Decheva, R. and I. Khardalov, Properties and use of sodium alginate obtained from the
1970 Bulgarian alga Cystoseira barbata in the textile industry. Khim.Ind.Sofia, 3:111-7 (in Bulgarian)

De Goracuchi, C., et al., Caratteristiche fisico-chimiche del polisaccaride solfato
1969 dell'Hypnea musciformis e loro variabilità stagionale. Boll.Soc.Adriat.Sci. Trieste, 57:1-22

De Toni, G.-B. and A. Forti, Contribution à la flore algologique de la Tripolitaine et de
1913 la Cyrénaïque. Ann.Inst.Océanogr.Monaco, 5(7):56 p.

Diannelidis, T., Greek marine flora and its utilization. Prakt.Hellen.Hydrobiol.Inst.,
1949 3(2):71-84 (in Greek, English summary)

Drew, E.A., Photosynthesis and growth of attached marine algae down to 130 metres in the
1969 Mediterranean. Proc.Int.Seaweed Symp., 6:151-9

Ercegović, A., Sur les cystoseira adriatiques. In Fauna e flora Adriatica, Split,
1952 Institut d'Océanographie et des Pêches, 212 p. (in Serbo-Croatian with extensive summary in French)

Favretto-Gabrielli, L., Ricerche sulle possibilità di sfruttamento economico delle alghe
1969 dell'Alto Adriatico. Metalli nelle alghe del golfo di Trieste. Rass.Chim., 2:76-80

Favretto-Gabrielli, L. and G. Pertoldi-Marletta, Ricerche sulla possibilità di sfrutta-
1969 mento economico delle alghe dell'Alto Adriatico. Cloro, bromo e idio nelle alghe del golfo di Trieste. Tec.Ital., (34)

Feldmann, J., L'utilisation des algues marines en France. Proc.Int.Seaweed Symp., 1:88-9
1953

Gaillande, D. de, Peuplements benthiques de l'herbier de Posidonia oceanica, de la
1970 pelouse à Caulerpa prolifera et du large du Golfe de Gabès. Tethys, 2(2): 373-84

Gessner, F. and L. Hammer, Die Primärproduktion in mediterranen Caulerpa-Cymodocea-
1960 Wiesen. Bot.Mar., 2(1/2):157-63

Giaccone, G., Contributo allo studio fitosociologico dei popolamenti algali del
1968 Mediterraneo orientale. G.Bot.Ital., 102(6):485-506

__________, Stato attuale della ricerca algologica in Italia e le sue possibilità di
1970 applicazione industriale. In Possibilità di utilizzazione industriale delle alghe in Italia. Vol.5. Dagli incontri tecnici. C.N.R. Laboratorio di tecnologia della pesca ed Ente fiera internazionale della pesca, Ancona, 5 luglio 1970. Falconara Marittima, Tecnografica, pp. 5-13

Giordani Soika, A., Le alghe in terapia. In Ospedale al mare, Venezia, pp. 419-44
1966

Güven, K.C. and E. Aktin, Studies on antilipaemic and anticoagulant properties of the
1964 algae collected from Turkish coasts. Bot.Mar., 7:1-3

Hoppe, H.A., Marine algae as raw materials. Bot.Mar.Handb., 1:126-287
1969

Hoppe, H.A. and O.J. Schmid, Commercial products. Bot.Mar.Handb., 1:288-368
1969

Ionescu, A., Productivity of the alga Ulothrix in Lacu Sarat and in laboratory cultures.
1970 Rev.Roum.Biol.-Bot., 15(2):103-9

Kalugina, A.A. and O.A. Lachko, The situation and distribution of the Phyllophora biomass
1968 in the region of the Zernov Phyllophora field in the Black Sea. Tr.Azov.-Chernomorsk.Nauchno-Issled.Inst.Morsk.Rybn.Khoz.Okeanogr., 27:121-32

Kireeva, M. and T. Schapova, Materials on systematic composition and biomass of the sea-
1957 weed and the highest vegetation of the Caspian Sea. Tr.Inst.Okeanol., 23: 125-37 (in Russian)

Larkum, A.W.D., E.A. Drew and R.N. Crosset, The vertical distribution of attached marine
1967 algae in Malta. J.Ecol., 55(2):361-71

Lausi, D., Studi sulla produttività primaria del fitobenthos nel golfo di Trieste.
1967 Quantità di clorofilla negli ecosistemi bentonici del golfo di Trieste. Nova Thalassia, 3(3):1-29

Lausi, D. and P. de Cristini, Studi sulla produttività primaria del fitobenthos nel golfo
1967 di Trieste. Osservazioni sulle variazioni periodiche del contenuto in acido alginico in Fucus virsoides. Nova Thalassia, 3(4): 1-16

Lewin, R.A. (Ed.), Physiology and biochemistry of algae. New York, Academic Press, 929 p.
1962

Lokar, A., Sugli oligosaccaridi e sui polisaccaridi delle alghe dell'Alto Adriatico.
1967 4. Determinazione del contenuto di laminarina di alcune Phaeophyceae. Pubbl. Fac.Econ.Commer.Ist.Merceol.Univ.Trieste, 13

Maldura, M.C.M., Perspectives d'utilisation des algues de la Méditerranée. Proc.GFCM, 1:
1952 66-70

Mautner, H.G., The chemistry of brown algae. Econ.Bot., 8(2):174-92
1954

Minio, M. and N. Spada, Distribuzione e polimorfismo di Gracilaria confervoides (L).
1950 nella laguna di Venezia. Pubbl.Ist.Stud.Adriat., (3)

Mohammed, A.F. and Y. Halim, Agar from Egyptian seaweeds. Am.J.Bot., 30:689-90
1952

Munda, I., Relation between the amount of physodes and reducing compounds in some Adriatic
1962 brown algae. Acta Adriat., 10:3-11 (in Slovenic with English summary)

__________, The quantity of alginic acid in Adriatic brown algae. Acta Adriat., 11(28):
1964 205-13 (in Slovenic with English summary)

__________, The production of biomass in the settlements of benthic marine algae in the
1972 Northern Adriatic. Bot.Mar., 15(4):218-44

Neushul, M., Final report of activities in Israel during September 1968 (Extracts).
1969 In Biota of the Red Sea and the Eastern Mediterranean. Interim Report of the Joint Research Project. Jerusalem, The Hebrew University of Jerusalem and the Smithsonian Institution, pp. 122-5

Nizamuddin, M. and W. Lehnberg, Studies on the marine algae of Paros and Sikinos Islands,
1970 Greece. Bot.Mar., 13:116-30

Parenzan, P., La *Cladophora prolifera* Kütz. dal golfo di Taranto e possibilità di una
1970 sua valorizzazione economica. *In* Possibilità di utilizzazione industriale delle alghe in Italia. Vol.5. Dagli incontri tecnici. C.N.R. Laboratorio di tecnologia della pesca ed Ente fiera internazionale della pesca, Ancona, 5 luglio 1970. Falconara Marittima, Tecnografica, pp. 14-21

Pérès, J.M. and J. Picard, Nouveau manuel de la bionomie benthique de la mer Méditerranée.
1964 *Rec.Trav.Stn.Mar.Endoume*, (31-47):137 p.

Pertoldi-Marletta, G., Sugli oligosaccaridi e sui polisaccaridi delle alghe dell'Alto
1967 Adriatico. 5. Determinazione del contenuto di fucoidina in alcune Phaeophyceae. *Pubbl.Fac.Econ.Commer.Ist.Merceol.Univ.Trieste*, (34):5-15

Pertoldi-Marletta, G. and L. Favretto-Gabrielli, Ricerche sulle possibilità di sfrutta-
1967 mento economico delle alghe dell'Alto Adriatico. 3. Il contenuto di fluoro, cloro, bromo e iodo di alcune Phaeophyceae e Rhodophyceae. *Pubbl.Fac.Econ. Commer.Ist.Merceol.Univ.Trieste*, (41):5-17

Pottier, J., Etude sur les possibilités d'utilisation des plantes marines tunisiennes
1929 pour la nourriture du bétail. *Ann.Inst.Océanogr.Monaco*, 6(3):321-64

Salem, H.M., A.F. Abdel-Fattah and M.M. Hussein, Biochemical studies on marine algal
1971 constituents. 4. Preparation of acetyl alginic acid from the Egyptian brown algal species *Cystoseira barbata* and evaluation of the acetyl process. *U.A.R. J.Chem.*, 14(3):297-302

Samaan, A.A., Extraction of agar from drifted seaweeds. *Notes Mem.Hydrobiol.Dep.U.A.R.*,
1960 (60)

Schiffner, V. and A. Vatova, Le alghe della laguna di Venezia. Sezione 1. Chlorophyceae,
1938 Phaeophyceae, Rhodophyceae (Appendix: Myxophyceae). *In* La Laguna di Venezia, Redatta da Gustavo Brunelli, *et al.*, Vol. 3, Parte 5, Tomo 9, Fasc.1:83-250

Simonetti, G., I popolamenti naturali di *Gracilaria confervoides* Grev. nell'Alto Adriatico
1970 in rapporto alla possibilità di coltivazione in ambienti controllati. *In* Possibilità di utilizzazione industriale delle alghe in Italia. Vol.5. Dagli incontri tecnici. C.N.R. Laboratorio di tecnologia della pesca ed Ente fiera internazionale della pesca, Ancona, 5 luglio 1970. Falconara Marittima, Tecnografica, pp. 22-5

Simonetti, G., G. Giaccone and S. Pignatti, The seaweed *Gracilaria confervoides*, an
1970 important object for autecological and cultivation research in the northern Adriatic Sea. *Helgo.Wiss.Meeresunters.*, 20:89-96

Smith, F. and R. Montgomery, The chemistry of plant gums and mucilages. *Am.Chem.Soc.*
1959 *Monogr.Ser.*, (141)

Sordina, J.B., Seaweeds of the Island of Corfu. *Proc.Int.Seaweed Symp.*, 1:24
1953

Spain, Sindicato Nacional de Industrias Quimicas, Subgrupo de Derivados de Algas, La
1968 industria de derivados de algas en España. Paper presented to the Sixth International Seaweed Symposium, Santiago de Compostela, 9-13 September 1968, 85 p. (with text also in English and French)

Špan, A., Quantities of the most frequent Cystoseira species and their distribution in
1969 the central and northern Adriatic. *Proc.Int.Seaweed Symp.*, 6:383-7

______, Some observations on the growth rate and growth rhythm of species *Cystoseira*
1969a *barbata* J.Ag. in the Adriatic. *Thalassia Jugosl.*, 5:337-44

Stirn, J., The pollution of the Tunis Lake. Rev.Int.Océanogr.Med., 9:99-106
1968

Zenkevitch, L., Biology of the seas of the USSR. London, Allen and Unwin, 995 p.
1963

FISHING AREA 41 : SOUTHWEST ATLANTIC

1. Brazil

In the north of Brazil an extensive programme for seaweed utilization is being launched. The Algimar company has built three factories in the states of Rio Grande do Norte, Ceará and Paraíba and organized 165 collection centres over about 2 000 km of coastline, giving work to 24 000 people. Strong support is given by the Brazilian Government; the enterprise constitutes part of a project for developing the northeast coastal region. The main harvests are of Hypnea and Gracilaria; other species being collected are Agardhiella, Eucheuma, Digena, Gelidiella, Gelidium, Pterocladia, Dictyota and Sargassum. The factories making agar, alginates and carrageenan have a capacity of 500 t of each, and also make seaweed meal. Most recent figures for production (1973?) comprise 144 t agar, 960 t alginates and 11 520 t seaweed meal, corresponding to harvests of some 14 400 t agarophytes, 96 000 t alginophytes and 55 000 t wet weight of unspecified seaweeds. The production is correlated to the development of stock-raising in the inner parts of the country. There are close to 100 million head of cattle in Mato Grosso. The transport of meat to coastal consumption areas could not be carried out without considerable losses in quantity and quality if the pieces of cut meat were not given a thin cover of alginate before deep freezing. It is anticipated therefore that any quantity which can be produced will be consumed within the country and only dry raw material in excess of the factories' capacity will be exported (de Sternberg, personal communication). The algae of the whole area were described by Taylor (1931, 1960).

Out of 201 species of marine algae found in the northeastern states of Brazil by Pinheiro-Vieira and Ferreira (1968) they selected 21 species, all red algae, as being of industrial interest. Of these, four are very abundant: Gracilaria ornata, Gracilariopsis sjoestedtii, Hypnea musciformis and Bryothamnion seaforthii. A further seven are mentioned as abundant: Gracilaria cearensis, G. debilis, G. ferox, G. foliifera, Amansia multifida, Vidalia obtusiloba and Agardhiella tenera. The geographical, ecological and seasonal occurrence of these species is given. The bottom communities of the northeast Brazilian shelf are described by Kempf (1970). The most important feature is the dominance of calcarous algae such as Halimeda and Melobesiae.

For central and southern Brazil there are some extensive investigations of the flora: Joly, 1965, 1967; Yoneshigue-Braga, 1970, 1970a, 1971, 1972, 1972a. Humm and Williams (1948) have studied the agar from two Brazilian seaweeds. Hypnea musciformis var. hippuroides should contain more than 35 percent of its dry weight of an excellent quality agar.

No quantitative records are available.

2. Uruguay

A number of small shrubby red algae species inhabit the intertidal levels. Some are said to be processed by a branch factory of an Argentine industry. High relative humidity in the air is a problem for drying.

3. Argentina

The seaweed production of Argentina increased from 2 000 t in 1958 to 24 800 t in 1968. In 1973 the harvested quantities were composed of 1 700 t of brown algae, 21 400 t of red algae, and 1 200 t of miscellaneous aquatic plants (FAO, 1974).

Exports of marine algae and agar-agar amounted to U.S.$2.3 million in 1967, U.S.$1.3 million in 1968 and U.S.$1.1 million in 1969. They represented about 55 percent of the total exports of fishery products (H. Barlind, personal communication).

The seaweed flora has been treated by Taylor (1939), red algae by Pujals (1961, 1963), brown algae by Asensi (1966) and species of economic importance by Kühnemann (1970, 1970a). In the north of Argentina seaweed quantities are low. An investigation of trophic levels in the vicinity of Mar del Plata, 38°S, mentions Codium spp. and Dictyota sp. as the main primary producers among macroscopic algae (Olivier, Bastida and Torti, 1968a). A treatise on the littoral ecosystems between 12 and 70 m in the Mar del Plata region states that algae are absent in the studied area, which could be related to the lack of light below 12-15 m depth due to muddy waters (Olivier, Bastida and Torti, 1968).

In Golfo Nuevo at 42°37'S, another investigation of marine ecosystems has been performed giving a detailed classification of the biocenoses at different levels (Olivier, Kreibhom de Paternoster and Bastida, 1966). In the rocky sublittoral level of Puerto Pardelas, instead of the great Laminariales which are found in other areas, there is a rich community of Codium fragile, C. vermilara marking the upper boundary of that level.

A research station, initially for marine algae and now covering the whole field of marine biology, was set up near Puerto Deseado in Patagonia at 47°45'S. The Deseado River mouth bears tidal oscillations up to 6 metres. As the coast is often a smooth slope, there are very wide littoral and sublittoral belts with densely populated biotopes (Kühnemann, 1964, 1971). In this region, the marine flora is exceptionally abundant. There is kelp growing in 70 m of water. The Macrocystis holdfasts examined by M. Neushul resembled those of M. integrifolia. In Ushuaia, Tierra del Fuego (water temperature 5°C) Macrocystis grew luxuriantly in about 2 m of water. Here it had the appearance of M. angustifolia (North, 1958).

Macrocystis predominates amongst the seaweeds on the Patagonian and Tierra del Fuego coasts up to the Malvinas (Falkland) Islands. Together with the Macrocystis beds of Chile this may very well constitute one of the largest seaweed resources of the seas. Ecology and norms for exploitation are being investigated. Other seaweeds are of the genera Corallina, Gymnogongrus, Porphyra, Gigartina and Polysiphonia (Nicola and Pecora, 1953). A comprehensive study of the species of the region was made by Skottsberg (1921, 1923).

Primarily Gracilaria and Gigartina are actually being exploited on the Patagonian coast, and on a smaller scale Porphyra and Macrocystis (A.O. Asensi, personal communication).

REFERENCES

Asensi, A.O., 1966 Guia para reconocer los generos de algas pardas de la Argentina. Contrib. Inst.Antartico Argent., (103):51 p.

FAO, 1974 Yearbook of fishery statistics. Catches and landings, 1973. FAO Yearb.Fish.Statist., 36:pag.var.

Humm, H.H. and R.H. Williams, 1948 A study of agar from two Brazilian seaweeds. Am.J.Bot., 35:287-92

Joly, A.B., 1965 Flora marinha do litoral norte do estado de São Paulo e regiões circumvizinhas. Bol.Fac.Fil.Ciên.Let.USP Botânica, (21):267 p.

______, 1967 Generos de algas marinhas da costa atlantica latino-americana. São Paulo, Edit. Universidade de São Paulo, 464 p.

Kempf, M., 1970 Notes on the benthic bionomy of the N-NE Brazilian shelf. Mar.Biol., 5(3): 213-24

Kühnemann, O., 1964 Biological marine station "Puerto Deseado". Proc.Int.Seaweed Symp., 4: 222-5

________, 1970 Algunas consideraciones sobre los bosques de Macrocystis pyrifera. Physis, 29:273-96

________, 1970a La importancia de las algas marinas en Argentina. Contrib.Tech.Cent.Invest. Biol.Mar.B.Aires, (5):35 p.

________ 1971 Vegetación marina de la Ria de Puerto Deseado. Contrib.Cient.Cent.Invest. Biol.Mar.B.Aires, (30):125 p.

Nicola, O.F.F. and E.J. Pecora, 1953 Seaweed resources of the Argentine. Proc.Int.Seaweed Symp., 1:104

North, W., 1958 Experimental ecology. Quarterly progress report. Kelp investigation program, 1 October-31 December 1957. Univ.Calif., Inst.Mar.Res., IMR Ref. 58-3:8-18

Olivier, S.R., R. Bastida and M.R. Torti, 1968 Resultados de las campañas oceanográficas Mar del Plata, 1-5: Contribución al trazado de una carta bionómica del area de Mar del Plata. Las asociaciones del sistema litoral entre 12 y 70 m de profundidad. Bol.Inst.Biol.Mar., Mar del Plata, (16):1-85

________ 1968a Sobre el ecosistema de las aguas litorales de Mar del Plata: niveles tróficos y cadenas alimentarias pelágico-demersales y bentónico-demersales. Publs.Serv.Hidrogr.Nav.Argent., (H1025):45 p.

Olivier, S.R., I. Kreibhom de Paternoster and R. Bastida, 1966 Estudios biocenoticos en las costas de Chubut (Argentina). 1. Zonación biocenológica de Puerto Pardelas (Golfo Nuevo). Bol.Inst.Biol.Mar., Mar del Plata, (10):74 p.

Pinheiro-Vieira, F. and M.M. Ferreira, 1968 Algas marinhas de interesse industrial para o nordeste Brasileiro. Bol.Estaç.Biol.Mar.Univ.Fed.Ceará, (20)

________, 1970 Quarta contribuição ao inventário das algas marinhas bentônicas do nordeste Brasileiro. Arg.Ciênc.Mar., 10(2):189-92

Pujals, C., 1961 Catálogo sistemático de las Rhodophyta argentinas. Rev.Mus.B.Aires

________, 1963 Catálogo de Rhodophyta citadas para la Argentina. Rev.Mus.Argent.Cienc. Nat."Bernardino Rivadavia" (Cienc.Bot.), 3(1):139 p.

Skottsberg, C., 1921 Marine algae. 1. Phoephyceae (Botanische Ergebnisse der Schwedischen. Expedition nach Patagonien und dem Feuerlande 1907-1909). K.Sven.Vetenskaps-akad.Handl., 61(11):1-56

________, 1923 Marine algae. 2. Rhodophyceae. K.Sven.Vetenskapsakad.Handl., 63(8):1-70

Taylor, W.R., 1931 A synopsis of marine algae for Brazil. Rev.Algol., 5:279-313

________, 1939 Algae collected by the Hassler, Albatross and Schmitt expeditions. 2. Marine algae from Uruguay, Argentina, the Falkland Islands and the Strait of Magellan. Pap.Mich.Acad.Sci., 24(1):127-64

Taylor, W.R., Marine algae of the eastern tropical and subtropical coasts of the Americas.
1960 Univ.Mich.Stud.Sci.Ser., (21):1-870

Yoneshigue-Braga, Y., Flora marinha bentônica da Baía de Guanabara e cercanias.
1970 1. Chlorophyta. Publ.Inst.Pesq.Mar.Rio de J., (042):55 p.

__________, Flora marinha bentônica da Baía de Guanabara e cercanias. 2. Phaeophyta.
1970a Publ.Inst.Pesq.Mar.Rio de J., (045):30 p.

__________, Flora marinha bentônica da Baía de Guanabara e cercanias. 3. Rhodophyta.
1971 1. Gonotrichales, Bangiales, Compsopogonales, Nemalionales e Gelidinales.
Publ.Inst.Pesq.Mar.Rio de J., (055):36 p.

__________, Flora marinha bentônica da Baía de Guanabara e cercanias. 3. Rhodophyta.
1972 2. Cryptonemiales, Gigartinales e Rhodymeniales. Publ.Inst.Pesq.Mar.Rio de J.,
(062):39 p.

__________, Flora marinha bentônica da Baía de Guanabara e cercanias. 3. Rhodophyta.
1972a 3. Ceramiales. Publ.Inst.Pesq.Mar.Rio de J., (065):49 p.

FISHING AREA 47 : SOUTHEAST ATLANTIC

The sparse information from Angola and Namibia seems to indicate that for the African west coast, south of Congo to the Tropic of Capricorn, the same can be said as for the coastline north of the Congo estuary: the shore waters do not provide such favourable conditions for the benthic algae as do the highly productive offshore waters for plankton.

1. Angola

From the north southward to the Moçamedes area the coast of Angola is rocky. The southern parts are sandy like the Southwest African ones.

Gelidium cartilagineum, Hypnea benguelensis and Peysonnelia capensis are agarophytes growing in quantities (Granger, 1964; Palminha, 1961, 1967, 1969; Palminha, Torres and Granger, 1963).

2. Namibia

Gracilaria verrucosa has been recorded from Walfish Bay and Lüderitz Bay (Isaac, 1956). No data on quantities are available.

3. Union of South Africa

The seaweed resources have been investigated by Isaac and Molteno (1953). According to their account, the two commercially important agarophytes are Gracilaria verrucosa and Gelidium pristoides. Gracilaria is cast up in amounts of about 1 000 t of dry weed annually along the 26 km of the Saldanha-Langebaan Lagoon northwest of Cape Town. For maps and details see Isaac, 1956. Originally, South African agar was obtained exclusively from this species, but since 1951 agar has been produced also from Gelidium pristoides. This species is not cast up and has to be collected from mid-tide levels. It is widely distributed in moderately warm waters and commercially collected along 120 km of coastline in the southern part of the east coast at the rate of about 80 to possibly 100 t dry weight per annum.

Of potential value for the manufacture of phycocolloids is Hypnea spicifera, which is abundant. Aeodes orbitosa and Gigartina radula have both been used for beer fining. An indication of the abundance of the latter is afforded by the claim that up to 100 t dry weight per annum can be obtained. Further potential agarophytes are Iridophycus capensis, Gelidium cartilagineum, G. amansii, Suhria vittata and Caulacanthus ustulatus. Porphyra capensis occurs in quantities but is not being utilized.

Algin-yielding kelps in sufficient amounts to be potential resources are Ecklonia maxima, Laminaria pallida and Bifurcaria brassicaeformis. The latter is abundant only between Cape Town and Cape Agulhas. Ecklonia is known as "bamboo seaweed", prefers warmer waters and is found on the west coast between Cape Agulhas and the Tropic of Capricorn, where it is cast up throughout the year in large quantities. Shuttleworth (1951) has estimated the drift weeds of Ecklonia and Laminaria at "many hundreds of thousands, if not millions, of tons". He does not indicate how he arrives at this estimate, and Isaac and Molteno (1953) state "there can be no doubts that Shuttleworth exaggerates the quantities of kelp on South African coasts". Nevertheless, Shuttleworth's extremely high values seem to be more frequently surviving in later selections of references even if, from the point of view of probability, Isaac and Molteno's reservations are the most appropriate. The latter give as an indication of quantities the estimate that from five enumerated localities only some 6 000 t dry weight of mostly Ecklonia can be collected annually. These localities represent but a small part of the total coastline along which kelp grow. Much of the west coast, however, is very inaccessible for commercial collection.

Suhria vittata is consumed in jellies.

REFERENCES

Granger, R., 1964 Contribuicão para o conhocimento da composiçao mineral da alga _Hypnea benguelensis_ Palminha. _Not.Mimeogr.Cent.Biol.Pisc.,Lisb._, (43)

Isaac, W.E., 1956 The ecology of _Gracilaria confervoides_ (L.) Grev. in South Africa with special reference to its ecology in the Saldanha-Langebaan Lagoon. _Proc.Int. Seaweed Symp._, 2:173-85

Isaac, W.E. and C.J. Molteno, 1953 Seaweed resources of South Africa. _J.S.Afr.Bot._, 19(3): 85-92. Summary also in _Proc.Int.Seaweed Symp._, 1:101-2

Palminha, F., 1961 A existência de algas agarófitas em Angola. _Not.Mimeogr.Cent.Biol.Pisc., Lisb._, (16):13 p.

__________, 1967 Sobre a distribuiçao e abundância de _Gelidium cartilagineum_ (L.) Gaillon na costa de Angola. _Not.Mimeogr.Cent.Biol.Aquat.Trop., Lisb._, (7):13 p.

__________, 1969 Observations sur _Peysonnelia capensis_ Mont. dans la côte de l'Angola. _Proc. Int.Seaweed Symp._, 6:297-301

Palminha, F., L. Torres and R. Granger, 1963 Uma alga de provável interesse económico na Baia de Benguela (_Hypnea benguelensis_ nov. sp.). _Not.Mimeogr.Cent.Biol.Pisc., Lisb._, (37):21 p.

Shuttleworth, R.G., 1951 The industrial potentialities of South African seaweed. _S.Afr.Ind. Chem._, 5

FISHING AREA 51 : WESTERN INDIAN OCEAN

1. Mozambique

No information available.

2. Madagascar

The south coast is rich in *Gelidium*. Some 300 t a year are harvested, of which 100 t are imported by Japan.

3. Mauritius

Very large amounts of seaweeds, in particular *Gracilaria*, are cast up on the beaches, but not used. Several people are employed to keep a hotel beach clean from decomposing algae.

4. Tanzania

The most important seaweed commercially is *Eucheuma striatum* and three or four other species of the same genus. The export of somewhat more than 700 t of dried matter (3 000 t wet weight) brings local incomes around 1.5 million shillings. *Eucheuma* growth is luxuriant - one single specimen of *E. platycladum* may weigh almost 1 kg. There is still plenty of *Hypnea*, which is not used. Potential resources not utilized are found in *Sargassum* and *Turbinaria*. The green sea lettuce *Ulva* appears as four species and is usually found in considerable amounts; in December it appears in masses (Jaasund, personal communication).

5. Kenya
6. Somalia
7. Ethiopia — No information available.

8. Sudan

The amounts harvested are estimated at 1 000 t a year.

9. Egypt

The lower littoral belt at Chardaga on the Red Sea coast is rich in brown algae such as *Sargassum*, *Cystoseira* and *Cystophyllum*. The tidal amplitude (100–120 cm) would permit harvesting by hand (Aleem, 1969).

10. Saudi Arabia

From the Farasan archipelago in the southern part of the Red Sea, Klausewitz (1967) reports a kelp forest strip of *Sargassum latifolium* and *Turbinaria descurrens*. Inside this there are sparse populations of *Cystoseira myrica*, and outside *Laurencia*. Good illustrations are given by Simonsen (1968). Species list and bibliography of Red Sea benthic algae are found in a comprehensive review by Papenfuss (1968).

11. Yemen Arab Republic
12. Democratic Yemen — No information available.

13. Oman

In four areas recently surveyed the total standing crop could be in the order of some 2 500 t of *Hypnea* and 28 000 t of *Sargassum*. These resources could form a base for the development of a seaweed fertilizer and feed additive industry in southern Oman.

14. United Arab Emirates
15. Qatar
16. Bahrain
17. Kuwait
18. Iraq
19. Iran — No information available.

20. Pakistan

There are nearly 900 km of shore to the Arabian Sea with upwelling water, rich in nutrients and plankton, but the open coastline, often with loose substrates, makes the shores less accessible for seaweeds and collectors.

Seaweed communities on various levels were described by Salim (1965). Most interesting as a possible resource is Gelidium pusillum, the dominant species from mid-tide level to the low water mark, which forms a dense matted growth on the rocks, especially on the shaded sides. The drift algae which are cast ashore by the incoming tide accumulate in large amounts especially in certain nooks and pockets on the rocky shore. Three communities of such landed drift algae are described. Along sandy coasts Sargassum, Botryocladia and Hypnea are dominant. In drift communities on rocky shores the same genera are represented among the dominant species, as are also Calliblepharis, Halymenia and Dictyota. Agardhiella and Gracilaria may also appear abundantly.

Only one investigation of quantities has been made covering the intertidal belt in two localities close to Karachi over a period of one year (Saifullah, 1973). It was found that production of seaweeds was high during the northeast monsoon season and low during the southwest monsoon, a period of strong winds and turbulent seas.

In the eastern parts of the localities investigated, brown algae made up 94 percent of the total weight of attached seaweeds, green algae the rest, while in the drift portion brown and red algae were present in almost equal proportions. In the other locality green algae dominated the samples of attached species, while red algae made up 98 percent of the drift. The dominant species was Hypnea musciformis which comprises 92 percent of the total algae. Evidently the drift material consisted of subtidal material only, which was cast ashore in a heap 2 m wide and with an average weight of 11 kg/m^2. The almost monospecific finding of a much demanded species seems promising while the quantities on the investigated part of the shore appear less encouraging for utilization.

The subtidal material still remains to be investigated but judging from the drift weed it will certainly contain considerable amounts of Hypnea. It seems reasonable to assume that Hypnea should be suitable for cultivation where the natural stands are so abundant. At Paradise Point the author found a rich cover of Porphyra sp. (Michanek, unpublished) not previously recorded from Pakistan but known since 1951 as an immigrant on the Visakhapatnam coast (Umamaheswara Rao and Sreeramulu, 1963). It should also be worth investigating the possibilities of cultivation of Porphyra.

21. India

21.1 Demand

Sixty percent of the population of India is estimated to be vegetarian. Considering the high total protein content in seaweeds, the algae constitute a potential resource of valuable supplementary food. Their possible contribution towards a complete nutrition further depends on the fact that their composition of amino acids differs from that of land plants and varies between species. Aspartic acid is the dominant one, followed closely by glutamin acid. In some algae proline, histidine, leucine and phenylalanine are found in large amounts (Central Salt and Marine Chemicals Research Institute, 1971).

At present, however, seaweeds are not used for human consumption in India to any extent comparable with the other countries in the Far East. The quantities harvested are taken by industry and it must be foreseen that all production in the near future resulting from increased harvesting of natural resources as well as that from marine cultures will most likely be used as industrial raw material. On the other hand, the seaweed chemists in the Central Salt and Marine Chemicals Research Institute propose to extract seaweed proteins and blend them into suitable food preparations. It has been

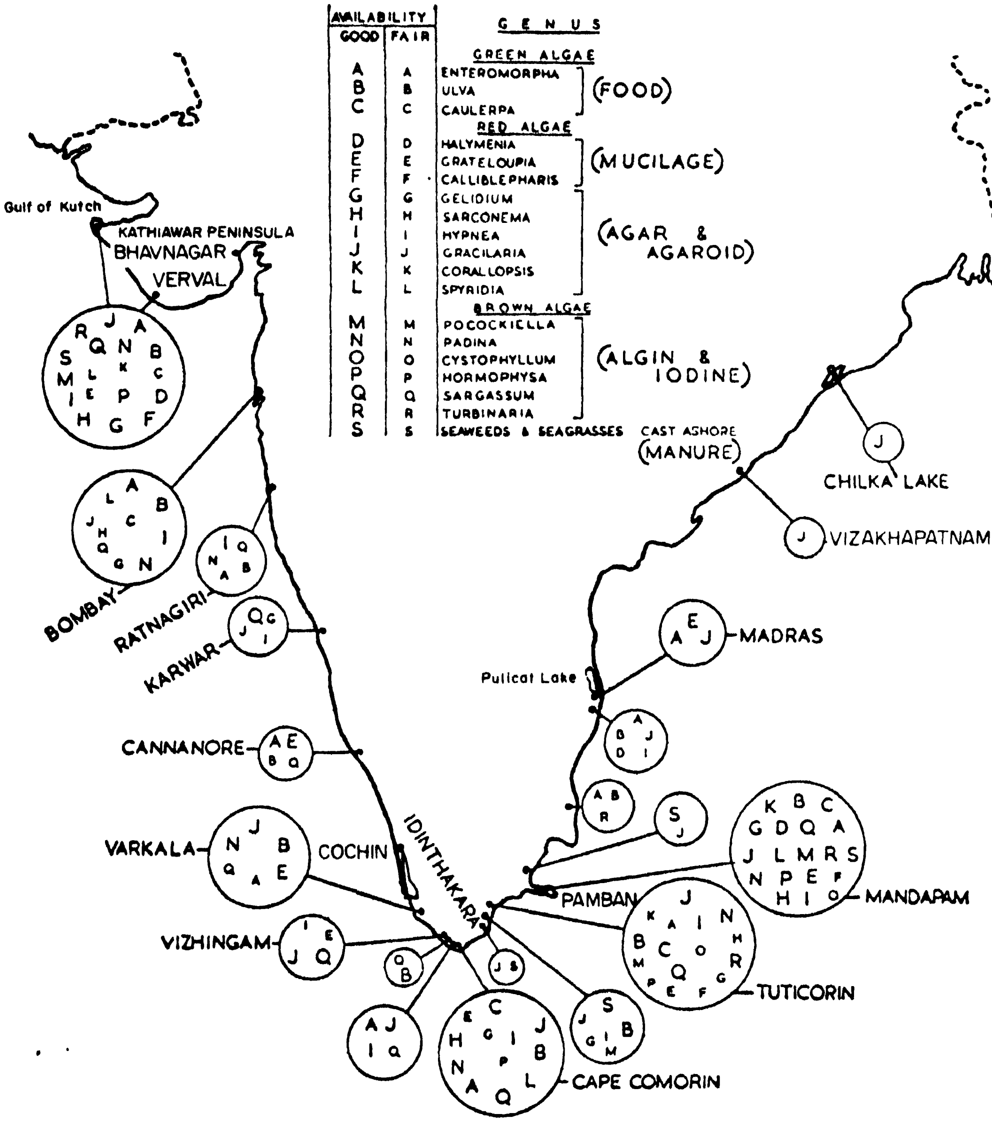


Figure 4. The distribution of the economic seaweeds of India.
(After Thivy, 1958)

claimed that proteins from green leaves are cheaper to extract, but they lack certain essential amino acids present in seaweeds. The industrial demand for seaweed raw material exceeds present production. About 60 t of alginate (for the textile industry) and 30 t of agar are imported every year. Demands are increasing and imports restricted (Desai, 1967). The agar is needed mainly for the preparation of cholera vaccine. The demand is 100 t, the present production only averages 50 t a year. About 60–70 t of sodium alginate per year is produced from about 700 t of dried Sargassum, harvested on the southern coast. There are plans for expansion in the near future and then the demand for raw material will be doubled (Chinoy and Vaidya, 1970). Even though export of dried seaweeds is now prohibited, the raw material is not sufficient for the present demands and cultivation of seaweeds is being taken up.

21.2 Distribution

Along the coastline of India, rocky or coral formations occur in the Mandapam and Kathiawar peninsulas and in the vicinities of Bombay, Ratnagiri, Karwar, Goa, Varkala, Vizhinjam, Visakhapatnam and a few other places like Chilka and Pulicat Lakes. Indian seaweed resources are restricted to these areas and to the Laccadive, Andaman and Nicobar Islands. The richest resources, however, and at present the only exploited ones, are found in the area from Mandapam, the tongue of land stretching towards Sri Lanka, down to Cape Comorin, the southernmost point of the Indian mainland, and along the Kathiawar peninsula, in the northern part of the west coast. The Indian seaweed resources, their taxonomy, chemistry, ecology and utilization are reviewed by Umamaheswara Rao (1970) who also gives a comprehensive list of literature.

The distribution of seaweed resources has been mapped by Thivy (1958) (Fig. 4) and by Umamaheswara Rao (1969). Thivy takes into account as many as 18 genera as well as seaweeds and sea grasses cast ashore and used as manure. Umamaheswara Rao concentrates on the four most important agar- and algin-producing genera: Gracilaria, Gelidiella, Sargassum and Turbinaria. Gracilaria species are found all around the coasts of India, G. lichenoides in lagoons and protected areas, attached to pebbles and shells on muddy substratum, G. crassa in shallow near-shore areas, G. verrucosa on sandy bottoms of the salt water lakes and other protected areas, its basal parts being buried in sand or attached to small stones. During the second world war agar was manufactured with Gracilaria species at the University of Travancore. A cottage industry method was developed at the Central Marine Fisheries Research Institute in Mandapam using G. lichenoides (Thivy, 1960). Gelidiella acerosa (= Gelidium rigidum) is found on surf-exposed areas of the coral reefs and is therefore restricted to the Mandapam area and the north-western part of Kathiawar peninsula (Umamaheswara Rao, 1969). This is mentioned as the most important species for the manufacture of agar, giving the highest agar yield and its agar showing the highest gel strength. In the Mandapam area it occurs in quantities of about 1.5 kg wet weight/m^2 of reef. At the time it was identified as Gelidium micropterum (Thivy, 1952; Boney, 1965).

Turbinaria (T. conoides and two more species) needs hard bottom and is found mainly on sheltered parts in the two coral reef areas already mentioned. Sargassum (51 species such as S. wightii) has the widest horizontal as well as vertical distribution. Very detailed records on brown algae are given by Misra (1966) in his chapters on distribution and seasonal succession.

21.3 Quantities of alginophytes

The standing crop has been estimated by Sreenivasa Rao, Iyengar and Thivy (1964) at the northwest end of Kathiawar. On 0.015 km^2 of a reef area they found 60 t of fresh Sargassum, which makes 4 kg/m^2. Hornell (1918) estimated the amount of fresh Sargassum washed ashore along the Kathiawar coast at about 100 t annually.

In the Gulf of Kutch, north of the Kathiawar peninsula, Desai (1967) gives the very high estimate of 100 000 t of harvestable brown algae per year corresponding to 10 000 t

dry weight. Chauhan and Krishnamurphy (1968) however, in the same area investigating a good 10 km^2, found 19 000 t fresh weight of algin-bearing seaweed, 12 000 t of which were *Sargassum*. Considering a life span of two years for *Sargassum* on the Gujarat coast, "it would be desirable to harvest only one-third of the available weeds in any one year". Four thousand tons of fresh *Sargassum* is sufficient to produce about 80 t of alginic acid.

21.4 Quantities of agarophytes

Prasanna Varma and Krishna Rao (1964) estimated the seaweed resources along the Pamban area in the Gulf of Mannar. In two sections covering 59 km^2, only 0.5 percent had coral or rocky reefs with economically harvestable seaweed resources; these 0.294 km^2 have an estimated wet weight of harvestable *Gracilaria* of 334.9 t, of *Gelidium* 18.9 t, of brown algae 657.9 t, or: agarophytes 1.2 kg/m^2, and alginophytes 2.2 kg/m^2. This estimate from these two localities equals or surpasses Thivy's (1960) estimate of the total Indian resources of dry agarophytes at possibly 35 t. Prasanna Varma and Krishna Rao state that on an average the red algae (*Gelidium micropterum* and Gracilarias) attained harvestable size in about two to three years while the brown algae (Sargassums, Turbinarias and *Cystophyllum muricatum*) required about four years. Recent studies by Raju and Venugopal (1971) and Umamaheswara Rao (1969, and unpublished) have shown that these brown algae grow to maximum height within one year and that *Gracilaria* spp. do not take more than six months to grow to harvestable size.

In Palk Bay, north of the Gulf of Mannar, Umamaheswara Rao (1968) estimated the standing crop in an area of 3.6 km^2. The mean values for two years of investigations were:

	Fresh weight (in tons)	kg/m^2
Agarophytes	140	0.04
Alginophytes	148	0.04
Edible algae	217	0.06
Other algae	428	0.12
Total	953	0.26
Sea grass	2 000	2.5

Sea grass quantities were calculated only for the area actually covered by phanerogams, 0.75 and 0.88 km^2 for the two years respectively. The mean total fresh weight was 2 000 t and mean density 2.5 kg/m^2.

A different kind of assessment, closer to the quantities available for industrial utilization, is given by Krishnamurthy *et al*. (1967). Over a period of three months they made daily collections of the drift seaweeds left ashore by the receding tide. At two stations - Pamban, the island ridge east of Mandapam, and Idinthakari, half way from there to Cape Comorin - they established ten sampling parcels of 10 m each within a distance of 1 km from the shoreline. The weeds were washed and sorted in seven groups, the fresh weight of which was recorded. Then they were separately dried and weighed again. The daily collections were added into monthly, for each of the seven species groups; the three months were, however, treated separately during the subsequent chemical investigations, which included moisture, ash, algin, agar and several inorganic components. Calculated total amounts of drift seaweed in tons fresh weight for both coastlines investigated were:

	Total	*Sargassum*	Other alginate weeds	*Gracilaria*	*Hypnea*	Other agaro-phytes	Other seaweeds
Idinthakari (10 km coastline)	61.5	45.4	0.7	2.1	0.7	0.4	11.3
Pamban (5 km coastline)	16.8	8.9	2.2	2.0	1.0	-	1.3

The total standing crop of agarophytes on Indian shores was estimated at 3 000 t fresh weight. This figure should be compared to estimates of 1 100 t for Korea and 700 000 t for Japan (Thivy, 1952; Boney, 1965).

Hypnea musciformis grows in abundance on the Gujarat coast and can be used as a source of agar-agar. Preparation and properties were studied by Ramarao and Krishnamurthy (1968).

Very high estimates exceeding 3 000 t of dry red algae were given by Desai (1967). From sampling in the Gulf of Kutch he concludes 20 t of dry Gracilaria can be harvested. Divers employed in the Gulf of Mannar in the richest ground for Gelidium in India observed a profuse 800 m wide growth all along the 32 km shoreline investigated between Mandapam and Tuticorn; 20 000 t of wet Gracilaria and 2 000 t of wet Gelidium, or 3 000 t and 300 t dry weight respectively, can be collected annually from this area.

Quantities of economic algae in three regions on the west coast of India were assessed and discussed in relation to substratum by Desai (1971).

Umamaheswara Rao and Nair have made a still unpublished study on seaweed resources, proceeding from data obtained during divings on the southwest and southeast coasts of India. The results will be available through the Director, Central Marine Fisheries Research Institute, Cochin 18, India.

21.5 Utilization

The dry weight and value of the agarophyte exports from India were:

1966	163 t	Rs.418 000	(U.S.$60 000)
1967	198 t	Rs.741 000	(U.S.$100 000)
1968	92 t	Rs.214 000	(U.S.$30 000)

Umamaheswara Rao (1969) pointed out that there was a vast scope for expanding the agar- and algin-yielding seaweed industry in the country. In order to ensure supplies to the local industry, export of such raw material is now prohibited.

One problem in prospecting the utilization of an agaroid resource is the fact that agar yield as found in laboratory extractions may be considerably higher than it is possible to obtain when working industrially.

	Percentage yield of agar	
	in laboratory	in industry
Gracilaria verrucosa	30–40	25–35
Gracilaria multipartita	40–50	17
Gracilaria edulis	up to 46	20–25
Gelidium amansii	35	23
Hypnea musciformis	53–57	15–20

(Desikachary, 1967)

It is claimed that the highest yield of agar in industrial scale extraction, viz. 37 percent, can be obtained by pulverizing the seaweed prior to extraction (Shrinivasan and Santhanraj, 1967).

In the district of Ramnad, porridge meal is prepared from sun-bleached, dry Gracilaria lichenoides and other Gracilarias, which are thoroughly washed in a grinding stone, soaked, ground fine and dried on organdy cloth in the sun.

In the districts of Ramnad, Tinnerelly and Cape Comorin, it is estimated that about 5 000 t of fresh seaweed and sea grasses are cast up on the shores annually yet, unaccountably, they are not conventionally used as manure. Their usefulness, however, was demonstrated in a field experiment with bendhi (Hibiscus esculentus) plants that received Hypnea compost and showed 73 percent increase in yield over those that received

cow dung and ash, fruiting reaching its peak a month earlier in the former set of plants (Thivy, 1958, 1960). Bokil, Mehta and Datar (1972) studied the effect of seaweed manure, farmyard manure, inorganic fertilizers and certain combinations of those, on pearl mullet, Pennisetum typhoids, and groundnut, Arachis hypogea. The results were comparable, but mostly not statistically significant. In general, the performance of treatments in which seaweed manure is included is better than other treatments.

21.6 Cultivation

Life history, nutritional requirements, amino acid composition, etc., have been studied at the Central Salt and Marine Chemicals Research Institute, Bhavnagar, on species of the genera already mentioned as well as on Ulva, Cystoseira and Hormophysa spp.

Following experimental cultivations of Gracilaria edulis near the Mandapam field station, the ideal time for planting was observed to be June–July. It was also found that three harvests could be obtained, the first in five months after planting, the second three months later, and the third a further two and a half months later. The annual yield has been calculated at 3.5 kg of fresh seaweed per metre of rope (CSMCRI, 1971; Raju and Thomas, 1971).

In cultivation experiments it was observed that there is a time lag of about 9–10 months before Sargassum is able to settle on an artificial substrate such as fresh concrete cylinders. Then the growth is fairly rapid as near-mature plants are seen within nine months after the appearance of young plants (Raju and Venugopal, 1971).

In addition to the method of soaking the cultivation substrate with spore-emitting agarophytes, manual transplantation of plant fragments is also used. From Gracilaria edulis fragments of 2.5–3 cm were most suitable for inserting into the twists of 7/8 inch coir ropes, as shown by Raju and Thomas (1971) in a paper richly illustrated to demonstrate the method of growing Gracilaria on ropes.

Gracilaria corticata, generally growing in the clear coastal waters of Veraval, was successfully cultured in turbid waters near Gopnath thus demonstrating its ability to survive and proliferate in such waters (Sreenivasa Rao, personal communication).

22. Sri Lanka

Commercially worthwhile quantities of seaweeds are found in three principal areas: Kalpitiya and Mannar on the west coast, and Trincomalee on the east coast; all of them on the northern half of the island. A map is given by Durairatnam and Medoof (1954).

"Ceylon moss", Gracilaria lichenoides (syn. G. edulis), is collected by hand in shallow water in the Kalpitiya district. It is the base of a small industry. Exports to England of dried bleached Ceylon moss were approximately 2.6 t in 1913 and 7 t in 1940. During the second world war, 9 t a year were exported to India, then this trade ceased. Efforts are now being made towards an increased utilization. It has been estimated that a minimum of some 18 t of dried seaweed could be produced annually, or with a conversion factor of seven, 126 t wet weight. In Trincomalee alone, about 75 t of Gracilaria verrucosa was collected in 1960. It would be possible, however, to produce at least 250 t from this coast (Durairatnam, 1956, 1961).

Along the southwest coast of Sri Lanka Sargassum grows mostly on dead coral reefs which are exposed at low tides. The quantities were surveyed by Durairatnam (1966) who found a harvestable total of 775 t wet weight; the dry weight of this would be 129 t. The dominant species is Sargassum cervicone, mature receptacles were observed in December and January. The best period for harvesting is December.

The large fields of species of Sargassum and Turbinaria in the very shallow waters of the north do not appear to have received the attention they deserve (Holsinger, 1952).

Gracilaria lichenoides, locally known as chan-show parsi, is used by Sri Lanka fishermen to prepare a kind of soup as well as pudding and jelly. Padina commersonii and P. tetrastromatica are both either eaten as salad or used to make a gelatine-like sweet (Subba Rao, 1965).

23. Maldives

The Maldive Islands are poor in species and especially in large and conspicuous algae. Sargassum is absent as in many Pacific atolls. Only in the southernmost atoll is the littoral colonized by macroscopic algae and turfs exposed on the reef flats instead of being confined to crevices. Some limiting factors are probably lack of nutrients, isolation and grazing by herbivorous fishes (Hackett, 1969).

24. French Southern Territories

Kerguelen has a number of fjords and islands providing a very long coastline with enormous amounts of Macrocystis pyrifera and Durvillea antarctica kelps and also enough red algae (Iridaea) to support a carrageenan industry. Recently, Kerguelen and Crozet Islands were covered by infra-red photos, still not evaluated. Ile Amsterdam is volcanic and has no archipelago. (Delépine, personal communication)

In the Baie du Morbihan on the east coast of Kerguelen as assessment of quantities has been made (Grua, 1964). Macrocystis covers 45 km^2 in the bay. In clear waters the population extends from 8–15 m, in less transparent waters from 1–12 m.

Locality	No. of stipes/m^2	Medium length of vegetation (m)	Total of stipes per m^2 (in m)	
Clear waters	20	25	500	95
Medium transparent	60	11–14	660–840	125–160
Least transparent	90–290	8–11	720–3190	137–606

The total biomass of Macrocystis in the bay was calculated at 6.3 million t. The undervegetation of Macrocystis in some of these stations amounted to:

Locality	Depth (m)	Inclination of substrate	Animals (%)	Algae (%)	Animals (kg/m^2)	Algae (kg/m^2)
Clear waters	15	horizontal	20	80	3.8	15.4
" "	15	vertical	80	20	10.2	2.5
Medium transparent	7	horizontal	11	89	0.6	5
Least transparent	5	vertical	90	10	108	12

The total biomass of the Macrocystis undergrowth was estimated at 2.8 million t in the parts of the bay covered by the kelp (Grua, 1964). Thus the total biomass of the Baie du Morbihan is 9 million t according to Grua. This figure could be compared to the wet weight of the total world harvest of seaweeds as we know it from the statistics – 800 000 t. Even if Grua's total is an overestimate by as much as 10 times, the fact remains that Kerguelen has one of the world's richest seaweed resources. Other parts than the bay investigated are also rich in seaweeds.

The hydrographic conditions of this luxuriant vegetation are interesting: 4–6°C, 20 microgramatoms of N/l and about 1.75 of P/l.

Aleem, A.A., Marine resources of the United Arab Republic. Stud.Rev.Gen.Fish.Coun.
1969 Mediterr., (43)

Bokil, K.K., V.C. Mehta and D.S. Datar, Seaweeds as manure 3. Field manurial trials on
1972 Pennisetum typhoids S.H. (pearl mullet) and Arachis hypogea (groundnut), Bot.Mar., 15:148-50

Boney, A.D., Aspects of the biology of the seaweeds of economic importance. Adv.Mar.
1965 Biol., 3:105-253

Central Salt and Marine Chemicals Research Institute, Annual report, 1969:44 p.
1971

Chauhan, V.D. and V. Krishnamurthy, An estimate of algin-bearing seaweeds in the Gulf of
1968 Kutch. Curr.Sci., 37(22):648

Chinoy, J.J. and B.S. Vaidya, Agar agar and alginate resources of India. Vidya, J.
1970 Gujarat Univ., 13:188-211

Desai, B.N., Seaweed resources and extraction of alginate and agar. In Proceedings of
1967 the Seminar on Sea, Salt and Plants, edited by V. Krishnamurthy, Bhavnagar, Central Salt and Marine Chemicals Research Institute, pp. 343-51

__________, Seaweeds of economic importance. J.Ind.Fish.Ass.Bombay, 8
1971

Desikachary, T.V., Seaweed resources of India. In Proceedings of the Seminar on Sea,
1967 Salt and Plants, edited by V. Krishnamurthy, Bhavnagar, Central Salt and Marine Chemicals Research Institute, pp. 7-24

Durairatnam, M., Methods of collection, cost of production and bleaching of Gracilaria
1956 lichenoides. Prog.Rep.Fish.Res.Stn.Ceylon, (2):54-6

__________, Economic marine algae of Ceylon. Occas.Pap.IPFC, (61):1-5
1961

__________, Quantitative survey of Sargassum along the south-west coast of Ceylon.
1966 Bull.Fish.Res.Stn.Ceylon, 19(1-2):1-2

Durairatnam, M. and J.C. Medcof, Ceylon's red seaweed resources. Ceylon Trade J., 19(4):
1954 1-6

Grua, P., Premières données sur les biomasses de l'herbier à Macrocystis pyrifera de
1964 Morbihan (Archipel Kerguelen). Terre Vie, 1964(2):215-20. Issued also in IIOE Collect.Repr., 4(209):91-6 (1967)

Hackett, H.E., Marine algae in the atoll environment: Maldive Islands. Proc.Int.Seaweed
1969 Symp., 6:187-91

Holsinger, E.C.T., Seaweed resources of Ceylon. Proc.Int.Seaweed Symp., 1:95
1952

Hornell, J., Report on the further development of fishery resources of Baroda State.
1918 Baroda

Klausewitz, W., Die physiographische Zonierung der Saumriffe von Sarso. "Meteor"
1967 Forschungsergeb.(D), 2:44–68. Issued also in IIOE Collect.Repr., 6(438):362–86 (1969)

Krishnamurthy, V., R. Venugopal, J.G. Thiagaraj and H.N. Shah, Estimating drift seaweeds
1967 on the Indian coasts. In Proceedings of the Seminar on Sea, Salt and Plants, edited by V. Krishnamurthy, Bhavnagar, Central Salt and Marine Chemicals Research Institute, pp. 315–20

Misra, J.N., Phaophyceae in India. In Monographs on algae, Indian Council of Agricultural
1966 Research, 230 p.

Papenfuss, G.F., A history, catalogue and bibliography of Red Sea benthic algae. Isr.J.
1968 Bot., 17:1–118

Prasanna Varma, R. and K. Krishna Rao, Algal resources of Pamban area. Indian J.Fish.,
1964 9(1):205–11

Raju, P.V. and P.C. Thomas, Experimental field cultivation of Gracilaria edulis (Gmel)
1971 Silva. Bot.Mar., 14(2):71–5

Raju, P.V. and R. Venugopal, Appearance and growth of Sargassum plagiophyllum (Mert)
1971 C.Ag. on a fresh substratum. Bot.Mar., 14(1):36–8

Ramarao, K. and V. Krishnamurthy, Study of the preparation and properties of the phyco-
1968 colloid from Hypnea musciformis (Wulf) Lamour from Veraval, Gujarat coast. Bot.Mar., 11:129–33

Saifullah, S.M., A preliminary survey of the standing crop of seaweeds from Karachi coast.
1973 Bot.Mar., 16:139–44

Salim, K.M., The distribution of marine algae along Karachi coast. Bot.Mar., 8(2):183–98
1965

Shrinivasan, R. and T. Santhanraj, Some studies on processing and utilization of sea weeds
1967 of Madras State. Madras J.Fish., 3:146–51

Simonsen, R., Zur Küstenvegetation der Sarso-Insel im Roten Meer. "Meteor" Forschungs-
1968 ergeb.(D), 3:57–66

Sreenivasa Rao, P., E.R.R. Iyengar and F. Thivy, Survey of algin-bearing seaweeds at
1964 Adatra Reef, Okha. Curr.Sci., 33(15):464–5

Subba Rao, G.N., Use of seaweeds directly as human food. Reg.Stud.IPFC, (2):32 p.
1965

Thivy, F., Investigations on seaweed products in India with a note on some properties of
1952 various Indian agars. Proc.IPFC, 3(2):173–5

__________, Economic seaweeds. In Fisheries of west coast of India, Bangalore, pp. 1–8
1958

__________, Seaweed utilization in India. In Proceedings of the Symposium on Algology.
1960 New Delhi, Indian Council of Agricultural Research

Umamaheswara Rao, M., The seaweed potential of the seas around India. In Proceedings of
1968 the Symposium on the Living Resources of the Seas around India, Cochin, 7–10 December 1968, Mandapam Camp, Central Marine Fisheries Institute, pp. 31

Umamaheswara Rao, M., Agar and algin-yielding seaweeds of India. Proc.Int.Seaweed Symp., 1969 6:715-21

__________, The economic seaweeds of India. Bull.Cent.Mar.Fish.Res.Inst.Mandapam Camp, 1970 (20)

Umamaheswara Rao, M. and T. Sreeramulu, Vertical zonation and seasonal variation in the 1963 growth of *Porphyra* on Visakhapatnam coast. Curr.Sci., 32:173-74

FISHING AREA 57 : EASTERN INDIAN OCEAN

Seaweeds are frequently consumed within the region. Large-scale harvesting for the manufacture of refined products with records on quantities is known only from Tasmania, Australia.

1. India (east coast N 10°N)

In the sea-connected Chilka Lake on the northeast coast it has been estimated that about 4-5 t of agarophytes are washed ashore annually.

In 1967 the harvesting centre Periypatnam on the Madras coast yielded in wet weight: *Gelidiella acerosa*, about 500 t, *Gracilaria lichenoides*, 155 t, *Sargassum* spp., 35 t (Umamaheswara Rao, 1969).

There are no records from the Andaman and Nicobar Islands.

2. Bangladesh

No information available.

3. Burma

Catanella impudica is sold in Rangoon for food. It is also known as Burmese moss or "Kyaukpwint". It is collected from the rocks at low tide, dried, dipped into hot water and eaten with oil, salt and prawns, like a salad (Kirby, 1953). Other red algae, mainly collected along the coasts of southern Burma, and regularly consumed, are *Bostrychia radicans*, *Gracilaria*, *Caloglossa* spp. and *Catanella nipae* (Boergesen, 1938; Subba Rao, 1965). *Gelidium*, *Sargassum*, *Chaetomorpha* and *Enteromorpha* are also eaten. Blue-green algae from fresh water (*Microcystis*) are taken from the water with a bamboo sieve squeezed and fried with dried shrimps.

4. Indonesia

See Area 71.

5. Australia

Tasmania, colder than most of the Australian continent, may have winter temperatures below 10°C, and is the only seaweed harvesting and processing area (Womersley, 1971, personal communication). The beds of *Macrocystis pyrifera* on the east coast of Tasmania have been estimated to yield 355 000 t fresh weight if three crops a year are taken. (This however is most likely an overestimate, maybe as much as 10 times too great, and may have contributed to certain difficulties for the processing factory.) They cover an area of 120 km^2, growing in depths of 3.5 to 30 m. The harvesting is highly mechanized. A specially designed vessel with blades similar to those on a hay mower cuts the weed at a depth of 1.2 m below the surface. The vessel has a crew of four men, a capacity of 20 t/h, with a carrying capacity of 45 t each trip. The company working in southeast Tasmania is now surveying prospects of harvesting new beds on the west coast of Tasmania and in Bass Strait (Anon., 1969).

In southern Australia there might be a further 1 400 000 t of *Macrocystis* (Chapman, 1970). It is not explained why this resource, alleged to be so much larger than that of Tasmania, is not utilized. The species in this area however is *M. angustifolia*, the sporophyte of which normally reaches 6 m (as compared to 60 m in Tasmanian *M. pyrifera*). It grows just above extreme low water to about 3 m below low water, usually forming a belt along the coast (Womersley, 1954). Consequently it is not available for mechanical harvesting.

An agar industry developed in Australia in the years of the second world war but ceased some years later when Japanese products came back on the market. It had been shown, however, that sufficient beds of Gracilaria confervoides existed in estuarine bays on the New South Wales coast and that a good quality of agar could be produced from it. A possible production of 100 t or more of agar per annum was estimated. At the end of the 1950s a Gracilaria export to Japan was started. In western Australia Eucheuma speciosum was used for agar, being harvested from drift weed only (Womersley, 1959). Storms, pollution and shipping have now removed the beds of Gracilaria in Botany Bay, near Sydney, which was one of the main regions (Womersley, personal communication).

The Australian Aborigines are reported to use certain species of seaweed, especially Sarcophycus potatorum, as food. The seaweed is dried and roasted, after which it is soaked in fresh water for about 12 h before consumption (Subba Rao, 1965). During the last century, and to some extent this century, Eucheuma speciosum and Pterocladia lucida were used for making jellies in Western Australia and Gracilaria was similarly used in Tasmania (Lucas, 1936; Wood, 1946).

REFERENCES

Børgesen, F., 1938 Catanella nipae used as food in Burma. J.Bot., 1938:265-71

Chapman, V.J., 1970 Seaweeds and their uses. London, Methuen and Co., 304 p.

Kirby, R.H., 1953 Seaweeds in commerce. London, HMSO, 157 p.

Lucas, A.H.S., 1936 The seaweeds of South Australia. 1. Introduction and the green and brown seaweeds. Adelaide, F. Trigg, Government Printer, 106 p.

Subba Rao, G.N., 1965 Use of seaweeds directly as human food. Reg.Stud.IPFC, (2):32 p.

Umamaheswara Rao, M., 1969 Agar and algin-yielding seaweeds of India. Proc.Int.Seaweed Symp., 6:715-21

Womersley, H.B.S., 1954 The species of Macrocystis with special reference to those on southern Australian coasts. Univ.Calif.Publ.Bot., 27(2):109-31

______, 1959 The marine algae of Australia. Bot.Rev., 25(4):545-614

Wood, E.J.F., 1946 Agar in Australia. Bull.CSIRO Aust., (203):43 p.

Anon., 1969 Harvesting giant brown kelp well established industry. Aust.Fish., 28(8):12-3, 17

FISHING AREA 61 : NORTHWEST PACIFIC

Japan is by far the world's largest producer of seaweed products. Official data for China are not available but production must be assumed to be very high. The Russian figures for "miscellaneous aquatic plants" are of limited value as they also include unspecified quantities of shellfish.

1. China

The Chinese have appreciated seaweeds in their food for at least 25 centuries. Most of it has been imported, as much of the coast is unfavourable for algal growth due largely to reduced salinity, paucity in nutrients, silty water and muddy bottoms in the north under influence from the major rivers, and too high water temperatures in the south. During the last 20 years, however, there has been a boom in kelp production. The dry weight output rose from 54 t in 1952 to 24 000 t in 1959. In terms of fresh weight this is equivalent to 328 t and 145 680 t respectively. The 1959 figure corresponds to estimates of the Japanese *Laminaria* harvest of kombu at the same time. The enormous effort resulting in this increase in kelp production is not only part of a programme to meet the nation's increasing demand for food. Kelp certainly is an inexpensive dish, favoured also by inhabitants of inland provinces, and is especially popular during the season when green vegetables are not readily available. A special reason for the Government to support this crop is the demand for iodine in China.

Before 1949 as much as 40 000–50 000 t of dried seaweed were imported annually (Cheng, 1968); Kirby (1953) quotes an average of 326 000 t for the years 1935–37.
In 1962 it was forecast that China's annual production would exceed 100 000 t dry weight within a few years. Chinese experts estimate, however, that to adequately meet the nation's demand for kelp as food and industrial raw material, an annual production of approximately 1 million t dry weight would be required. It is considered that through a maximal exploitation of possible resources even this could be achieved.

The abovementioned kelp production boom refers to one species only – *Laminaria japonica*, known as Haidai, "sea belt" – and the figures reflect a development from kelp production based on the natural growth on rocky bottoms to large-scale cultivation on bamboo tube rafts and on ropes. Details are given for two provinces (Cheng, 1968):

	Liaoning Province		Shantung Province			Culture by
	Floating raft	Sea floor	Floating raft	Sea floor	Total	raft method (percentage)
1952	0	72	62	0	134	46.4
1953	0	451	169	68	688	24.5
1954	15	813	457	244	1 529	31.0
1955	147	1 411	1 089	520	3 167	39.0
1956	243	701	2 107	305	3 356	70.0
1957	3 763	2 604	4 873	881	12 981	65.4
1958	18 397	4 539	13 207	1 378	37 521	84.2

The Government input in promoting this mass cultivation of *Laminaria japonica* can be expressed by the figures for algologists – 10 in 1949 and 1 000 in 1963, or for research institutions – one in 1949 and 23 in 1963. The fishermen (marine farmers) have been engaged in the so-called "three-fix policy" of the commune system, i.e., fixed production quotas, fixed catch or harvest quotas for sale to the commune administration at cut-rate prices, and fixed territories for fishing or aquaculture. Additional taxes are imposed upon workers who fail to join a commune. Technicians and skilled workers are trained. In Fukien Province alone 20 000 people had mastered the technique of kelp cultivation by the early 1960s.

A most important innovation is the extension of kelp culture to south China. While in 1958 production was still confined to the Liaoning and Shantung Provinces, since 1959 transplantations have been successfully made in the provinces of Kiangsu, Chekiang, Fukien and Kwantung (from 39°N to 23°N). Nurseries in Lüta (an area including Shanghai) produce 3 800 million young plants for China's seven coastal provinces. The methods for long-distance transportation of living young sporophytes (temperature, oxygen, moisture and micro-organism control), as well as the growth in waters warmer than within the natural range of distribution of the species, are described by Cheng (1968). He also gives details for single- and double-line bamboo tube rafts, for sea floor culture and "tiered farms" for kelp cultivation in intertidal pools constructed by means of dams built of rocks and cement.

The waters of the Yellow Sea are generally deficient in nitrate nitrogen, the content rarely exceeding 5 mg/m^3, an inadequate supply for commercial growth of kelp without the aid of supplementary fertilizers. Waters along the east and south China coasts contain larger amounts, e.g., 88–227 mg/m^3 around Choushan archipelago in Chekiang Province, and 86–123 mg/m^3 in Fukien Province. Even the most hostile waters of the Yellow Sea, however, have been made receptive to successful cultivation. Porous cylinders containing nitrates are suspended from the rafts, and during the growth of the young plants nutrients slowly seep out through the walls of the clay cylinders (Cheng, 1968). Chinese authorities are now considering another substitute source of fertilizer for Laminaria: large-scale introduction of nitrogen-fixing blue-green algae and bacteria into the Yellow Sea (Bardach, Ryther and McLarney, 1972).

Raft culture is reported to yield 8 t dry weight/hectare. Kelp on rocks or on stones deposited on the sea floor may yield more than 10 t/hectare in fertile locations and half as much in other places. One labourer can manage 2 hectares of sea floor culture. The annual cost for labour and materials averages U.S.$400 per 2 hectares, while the market value of the kelp produced is U.S.$8 000.

Around the estuaries of the large rivers water transparency may be limited to 10 cm. The subsequently poor penetration of light energy, however, does not prevent these areas from being used for cultivation, and in fact kelp cultured in such turbid waters grows 1–2 cm a day in length (Cheng, 1968).

The kelp species Ecklonia cava, Sargassum fusiformis and Undaria pinnatifida are also eaten in China, as well as a number of blue-green, green and red algae (Kirby, 1953; Chiu, 1958; Johnston, 1966; Chapman, 1970). A blue-green land alga Nostoc commune and its variety Nematonostoc flagelliforme are still used by the Chinese of the interior for food. The green algae Monostroma nitidum and Enteromorpha spp. are used for making spring rolls. Ulva pertusa and U. lactuca are mostly used for medical purposes. All these green algae grow abundantly in rather sheltered places around the coast of Hsiamen (Amoy). Three red seaweeds are also eaten in the Hsiamen region: Porphyra suborbiculata, also consumed in large quantities in the interior of Fukien, Gelidium divaricatum and Gracilaria verrucosa (Kirby, 1953). Digenea simplex has great economic importance as an antihelminthic. From tetrasporic plants of Gloiopeltis furcata a paste is obtained which is used for silk sizing. Over 500 t a year are gathered (Hoppe and Schmid, 1962).

Agar was originally produced in China and was introduced into Japan in 1662. The industry declined, however, and in 1937 China had only three factories, producing about 35 t.

In the coastal provinces farmers have used Sargassum species, in particular S. horneri, as a fertiliser for sweet potatoes, groundnuts, coconuts and coffee; often the ash from burnt weed is applied to the crops. Farmers prefer this to other fertilizers (Kirby, 1953).

2. Hong Kong and Macao

Hong Kong is known for its seaweed trade. In some cases where seaweeds have been sold as having Hong Kong origin, the quantities are too large to have possibly been harvested within the area. Local resources of importance are Ulva lactuca, Sargassum spp. and Porphyra suborbiculata (Chiu, 1958). A tea brewed from Sargassum or Laminaria is used against fever and blood diseases. An antihelminthic from Digenea is important. A paste for sizing silk is obtained from tetrasporic plants of Gloiopeltis (Chiu, 1956).

3. Democratic People's Republic of Korea

No information is available.

4. Republic of Korea

This is probably the world's third largest producer of seaweeds with regard to quantity and second largest with regard to value. The main area of cultivation is the south coast. The eastern coastline is steep, has rough weather, and there is no cultivation; the west coast has a turbid brackish surface water, poor in certain nutrients. The most important seaweeds quantitatively are the kelp Undaria, mainly produced from marine fisheries, and the laver Porphyra, exclusively from aquaculture. The main market for Korean-produced laver is Japan and production depends on the Japanese demand. Laver culture has progressed from 10 000 t in 1965 to 36 000 t in 1970, and at present the Office of Fisheries has no specific plan to further increase the total production but is concentrating on improving the quality and reducing production costs (Honda, 1970).

The following quantities of seaweeds (in thousands of tons fresh weight) were harvested in 1970 (FAO, 1971):

Brown		47.2	Red	35.8
Aquaculture (Mal, Mi-Yŏk)		6.6	Aquaculture (Porphyra)	
Marine fisheries		40.6	Green	1.2
Mal (Sargassum)	2.2			
Mi-Yŏk (Undaria)	38.4		Marine fisheries	

Miscellaneous aquatic plants		32.4
Aquaculture	1.9	
Marine fisheries	30.5	

The major species of laver currently cultured in Korea are Porphyra tenera (asakusa) P. yezoensis (susabi), P. seriata (ichimatsus) and P. kuniedai. Transplanting experiments have been carried out in the search for the best species and races. It is safe to transplant them from the time the sporelings can be seen with the naked eye until they have grown to 1 or 2 cm. During this time the sporelings can remain in a dry condition for three days and can therefore be transported long distances for transplanting. If the "green laver" Enteromorpha occurs, it can be eliminated by exposure to air for one day. This operation has to be done before the laver have reached more than 1 cm, as after that also the laver buds may be damaged by the drying.

As far as quality (lustre) and yield are concerned, horizontal culture methods are far superior to vertical culture methods. The "net hibi" installation produces a more tender laver than the generally used "split bamboo floating hibi" method. Laver collected after February shows gradual decline in quality standard. The main cause for this is the reduction of nutrient salts around the culture area at the same time as metabolism increases with rise in water temperature and increased hours of sunshine. The mean NO_3-N

content at Chikuto, a south coast station, during November-February is 63 mg/m^3, while at Tayato on the west coast the corresponding mean value is 29. At the end of March both stations are down in low values, 15 and 17 mg/m^3 respectively. The minimum nitrogen requirement for healthy laver growth is 30 mg/m^3. It is clearly evident that the locations of laver farms in Korea coincide with the area of higher content of N. Selection of sites for new laver culture is also based on the results of surveys of nutrient levels.

In view of the fact that in a bad year laver production goes down to half that of a good harvest, Chyung and Kim (1966) investigated the reasons for success and failure. It was found that bad years were connected with high sea water temperatures; > 13°C during initial stage of growth after budding gave a bad year and so did the same temperatures at the initial period of harvest.

In addition to Porphyra, Sargassum and Undaria, which are accounted for separately in the statistics, numerous other genera are utilised. 1 800 t wet weight of Gelidium amansii and other Gelidium spp. are collected from natural habitats on rocks. Included in "miscellaneous aquatic plants" are Pachymeniopsis spp. and Chondrus ocellatus. Among the red algae there are also certain resources of Gracilaria verrucosa, Gigartina tenella, Laurencia spp. and Chondria crassicaulis (J.W. Kang, Pusan Fisheries College, personal communication).

In order to increase the production of agarophytes, in particular Gelidium amansii, rocks are laid out and reefs are built. The agar-yielding species do not develop much during the first year and production should not be expected until the second year of operation. Further, the natural rocks are scrubbed and transplantations carried out.

Almost all agar-agar material landed has been collected by female skindivers, sometimes with diving equipment. The harvest per diver per day is 7-10 kg dry weight, which with a conversion factor of 4-5 makes about 35-45 kg wet weight. From Japan, 50-55 kg wet weight a day has been recorded. Boney (1965) quotes Thivy's 1952 estimate of the total agarophyte standing crop for Korea at 1 103 t fresh weight.

The green algae are Ulva pertusa, Enteromorpha spp. and Monostroma spp.

The brown alga Undaria pinnatifida is collected from its natural habitats which are traditionally extended by rock laying. Also uninhabited islets like the Dok-Do (Liancourt Rocks) in the Sea of Japan are occasionally visited by women skindivers collecting Undaria pinnatifida (Kang and Park, 1969). Rope cultures, like those widely used in Japan and China, have been introduced but are making slow progress as they require rather much investment and there is already a large natural production.

The Sargassum harvest is mainly from S. horneri, S. thunbergii, S. sagamianum and S. fulvellum. Another important brown alga is Hizikia fusiforme with the local name "tot". Over 500 t per year is harvested. There are also conspicuous resources of Ecklonia cava, E. stolonifera and Scytosiphon lomentaria (J.W. Kang, personal communication).

5. Japan

Japan is the leading nation in seaweed utilization not only with regard to the quantities actually harvested but also to traditions, techniques and diversified preparation for human consumption. In seaweed research Japan holds a top position. Consequently, Japanese methods for the cultivation of seaweeds and preparation of seaweed products have been reviewed by many authors: Bardach, Ryther and McLarney, 1972; Boney, 1965; Chapman, 1970; Dawson, 1966; Hoppe, 1966; Iversen, 1968; Kirby, 1953; MacFarlane, 1968; Okazaki, 1971; Subba Rao, 1965; Sundene, 1962; Tanikawa, 1971. For illustrations of cultivating and harvesting arrangements see in particular MacFarlane, Okazaki and Sundene. Various aspects of Japanese seaweed cultivation are treated by Furukawa, 1972; Iwasaki and Matsudaira, 1958; Kurogi, 1963; Kurogi et al., 1971, and Yamada, 1959.

5.1 Importance and demand

The seaweed fraction of the total landings of fishery products, including fishes, molluscs, seaweeds, crustaceans, pearls, whales and other marine animals, amounts to 5 percent of the weight but 10 percent of the value. Within the seaweed fraction *Porphyra* stands for 30 percent of the weight but 75 percent of the value. *Laminaria* is greater in bulk, 33 percent, but much lower in value, 11 percent. *Undaria* comes third with 22 percent and 9 percent respectively. The agar-agar yielding species represent 4 percent only in quantity and, surprisingly, a mere 2 percent of the value (Yamamoto Nori Research Laboratory figures for 1969).

The number of processing plants for dried seaweed products is as high as 160 000, or more than 80 percent of the total number of land-based Japanese fishery processing plants (Statistics and Survey Department, 1972). These figures reflect the fact that seaweed processing, and in particular that of nori, requires much manual labour and is to a large extent managed in small units, which are generally family enterprises.

Average yield of main seaweeds in tons dry weight (Okazaki, 1971)

Green :	*Ulva*	4 018
	Enteromorpha	3 973
Brown :	*Laminaria*	36 600
	Undaria	12 586
	Eisenia, *Ecklonia*	5 427
	Hizikia	2 369
	Alaria	1 300
	Eckloniopsis	428
	Sargassum	354
	Endarachne	152
	Nemacystus (*Mesogloia*)	115
	Heterochordaria	74
Red :	*Porphyra*	6 660
	Iridophycus	776
	Gloiopeltis	608
	Chondrus	565
	Pachymeniopsis	492
	Digenea	281
	Others	147
agaroids:	*Gelidium*, *Beckerella*	4 050
	Gracilaria	1 654
	Acanthopeltis japonica	179
	Campylaephora	132
	Pterocladia tenuis	131
	Ceramium	70
	Others	233
	Total	73 374

In addition to the seaweed produced in Japan, increasing quantities of raw material are imported. The following data are taken from Fisheries Statistics of Japan, 1969 (Statistics and Survey Dept., 1972):

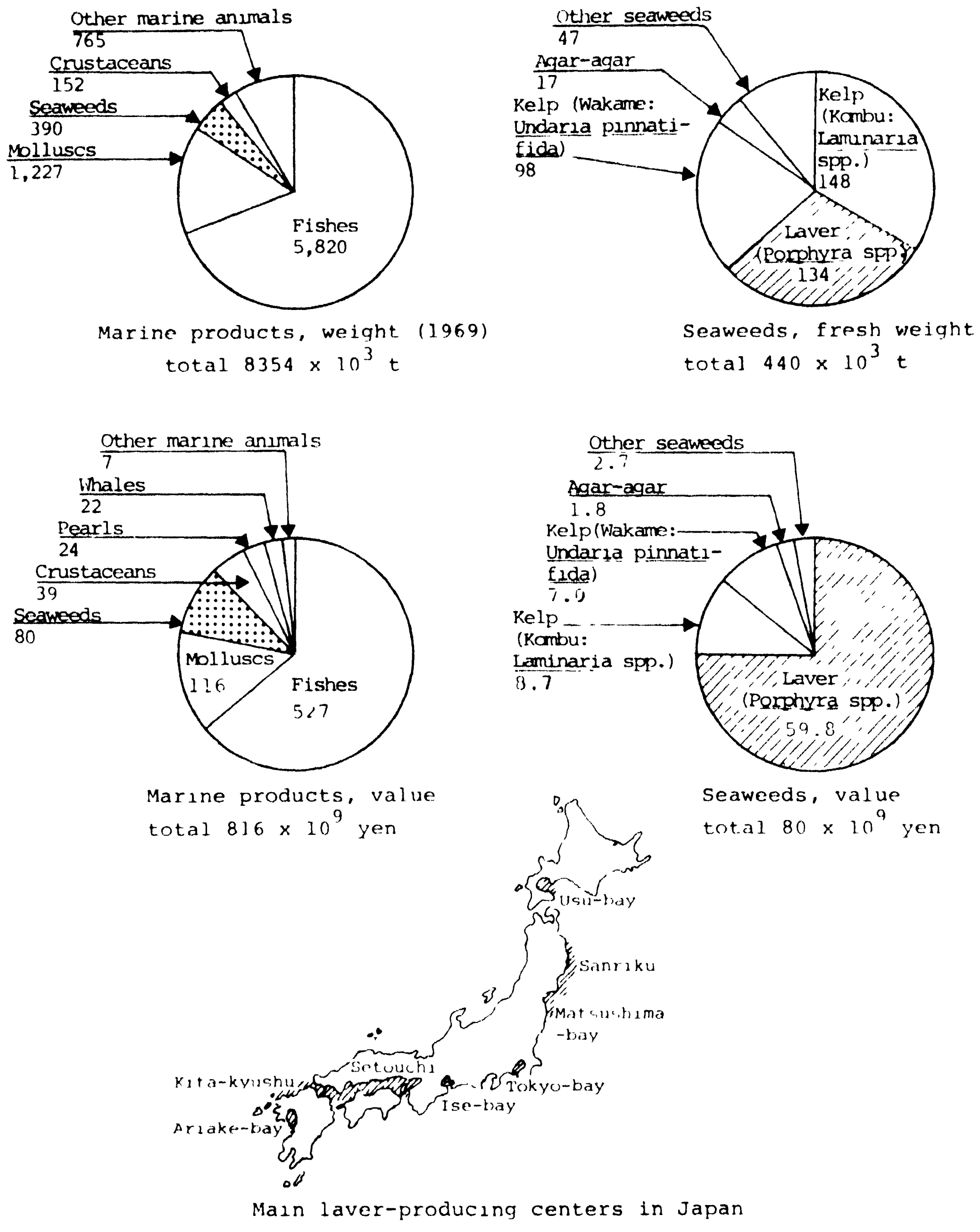


Figure 5. Quantities and value of marine products and laver production in Japan. (After Oohusa 1971)

Import of seaweed in million U.S. dollars

Year	Dried seaweeds	Raw agar-agar
1965	0	1.6
1966	9.7	5.3
1967	10.9	7.1
1968	16.5	2.3
1969	17.9	2.5

Country of origin and value of import in million U.S.$, 1969

Korea, Rep.	17.9	0
Chile		0.8
Argentina		0.6
South Africa		0.2
Australia		0.06
Mexico		0.06

It appears that "dried seaweed" means dried *Porphyra* and Korean "nori" only. The rapid growth of this importation explains why in Korea present efforts are directed towards meeting the quality demands and prices on the Japanese market. It also indicates how Japanese demand is growing faster than home production. "Raw agar-agar" may stand for certain dried red seaweed species only, which means that this breakdown does not cover the total import of seaweeds, brown algae like *Macrocystis* being omitted.

The exportation of agar from Japan totalled 700 t, valued at more than U.S.$ 4 million in 1967. The same year Japan imported 12 000 t of agarophytes. A Japanese top import of 2 285 t of *Gracilaria* in 1967 was abruptly cut down to 158 t the following year causing serious socio-economic problems for fishermen and dealers in exporting countries (Kim, 1970).

5.2 Distribution

Phytosociological aspects of the intertidal marine algae all around the coasts of Japan have been studied by Taniguti (1962), who regrettably gives no data on quantities. Hokkaido Island in the north and the northernmost part of the east coast of the main island, Honshu, are regarded as belonging to the subarctic region. In the natural flora the dominating community type is the *Fucus evanescens*-*Laminaria longissima* association.

The rest of the Japanese waters are under the influence of the warm current and are almost entirely classified as temperate. A typical open sea community is the *Hizikia fusiforme*-*Eisenia bicyclis* association, while the protected areas host various communities depending mainly on salinity. Most dominating and widely distributed is the *Monostroma nitidum*-*Scytosiphon lomentaria* association.

The south coast of Kyushu island is defined as subtropical. It is recognized by the *Gelidium pusillum*-*Corallina pilulifera* association. Since the repatriation of the Ryukyu Islands in 1972 the subtropical part of Japan extends almost to the tropic of Cancer. The barrier reef algal flora was described by Tanaka (1964).

5.3 Standing crops and total resources

A few examples of the standing crop of natural floras are given by Hayashida and Sakurai (1969) who found 1.1-1.2 kg/m^2 in the low tidal level not far from Shizuoka (southwest of Tokyo). *Sargassum ringgoldianum* was found as a dominant species all the year round; in August as the only dominant, in January together with *Pachymeniopsis*

lanceolata, in April with Eisenia bicyclis and Myagropsis myagroides, and in June with Hypnea charoides.

Mukai (1971), in a study of the phytal animals living on Sargassum serratifolium, found standing crops of the alga of 4.9 and 3.5 kg/m^2 in the most luxuriant season and 0.5–0.5 kg/m^2 in the off-season. The change in the standing crop/m^2 agreed with the change in wet weight of the individual alga, since no change in density of number of plants was obtained.

The distribution of the utilized species as reflected in harvest records is particularly interesting. The entire production of Laminaria, Heterochordaria and Alaria is restricted to the subarctic region, within which on the other hand only 1 percent of the Porphyra yield is produced. In the far south the very small area of subtropical water produces 80 percent of the Digenea and 5.5 percent of the Gelidium yield. Undaria is distributed and collected all around the main and southern islands, including the subtropical waters, as well as in the north along the west and southwest of Hokkaido. Of the total production, however, at least two-thirds is yielded within the comparatively minor part of the distribution area which is classified as subarctic (Okazaki, 1971).

Average total harvest in tons dry weight (dominating genera indicated)

Prefectures with coasts in subarctic waters

Hokkaido	40 667	Laminaria, Undaria, Alaria
Miyagi	3 993	Undaria, Laminaria, Porphyra
Iwate	3 847	Undaria, Laminaria
Aomori	1 831	Undaria

Prefectures with coasts in temperate waters (southeast of Honshu)

Mie	[illegible] 424	Ulva, Eisenia/Ecklonia, Enteromorpha
Chiba	[illegible] 976	Porphyra, Enteromorpha, Gracilaria
Shizuoka	1 833	Gelidium, Ulva, Eisenia/Ecklonia
Aichi	1 784	Porphyra
Tokyo	1 659	Gelidium, Porphyra

Subtropical coast prefecture

Kagoshima	919	Undaria, Digenea, Gelidium

A breakdown into 20 genera groups for all [illegible] prefectures in Japan is found in Okazaki (1971) from which these data were selected. A present trend, however, is that Porphyra in Tokyo (780 t in Okazaki's table) cannot be cultivated any more, due to sea water pollution and reclamation. A Porphyra cultivation should be added to Mie prefecture (previously 290 t) where it now flourishes remarkably (T. Oohusa, personal communication).

5.4 Quantities and cultivation of Porphyra - "Nori", "Asakusanori"

Porphyra species grow intertidally, forming gelatinous, purple sheets, as a rule consisting of a single layer of cells only. After harvesting they are dried and processed into a product called nori, which is sold in bundles of ten sheets measuring 19x17 cm. The weight of each sheet is 3 g.

A nori sheet is the result of drying a mixture of chopped laver and fresh water on a framed screen, and should not be mistaken for the dried leaf-like thallus of one Porphyra plant. The word "nori" is used for the Porphyra plant as well as for the marketed product. It is extended by the addition of prefixes to include, for example, Gracilaria - "ogonori", Gloiopeltis - "funori", and even brown algae such as Endarachne - "habanori", and green

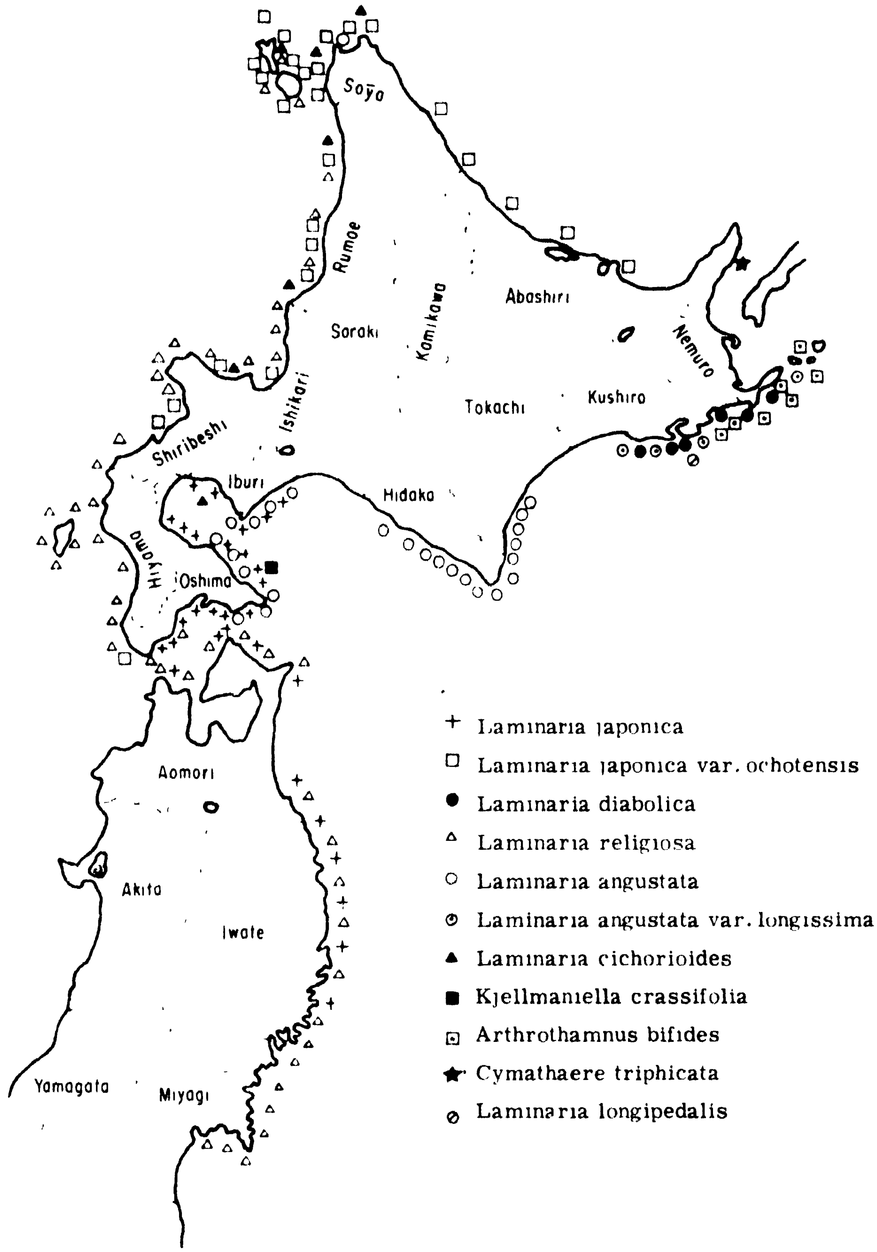


Figure 6. **Harvesting sites of edible <u>Laminaria</u>, <u>Kjellmaniella</u>, <u>Arthrothamnus</u> and <u>Cymathaere</u>.** (From Okazaki, 1971)

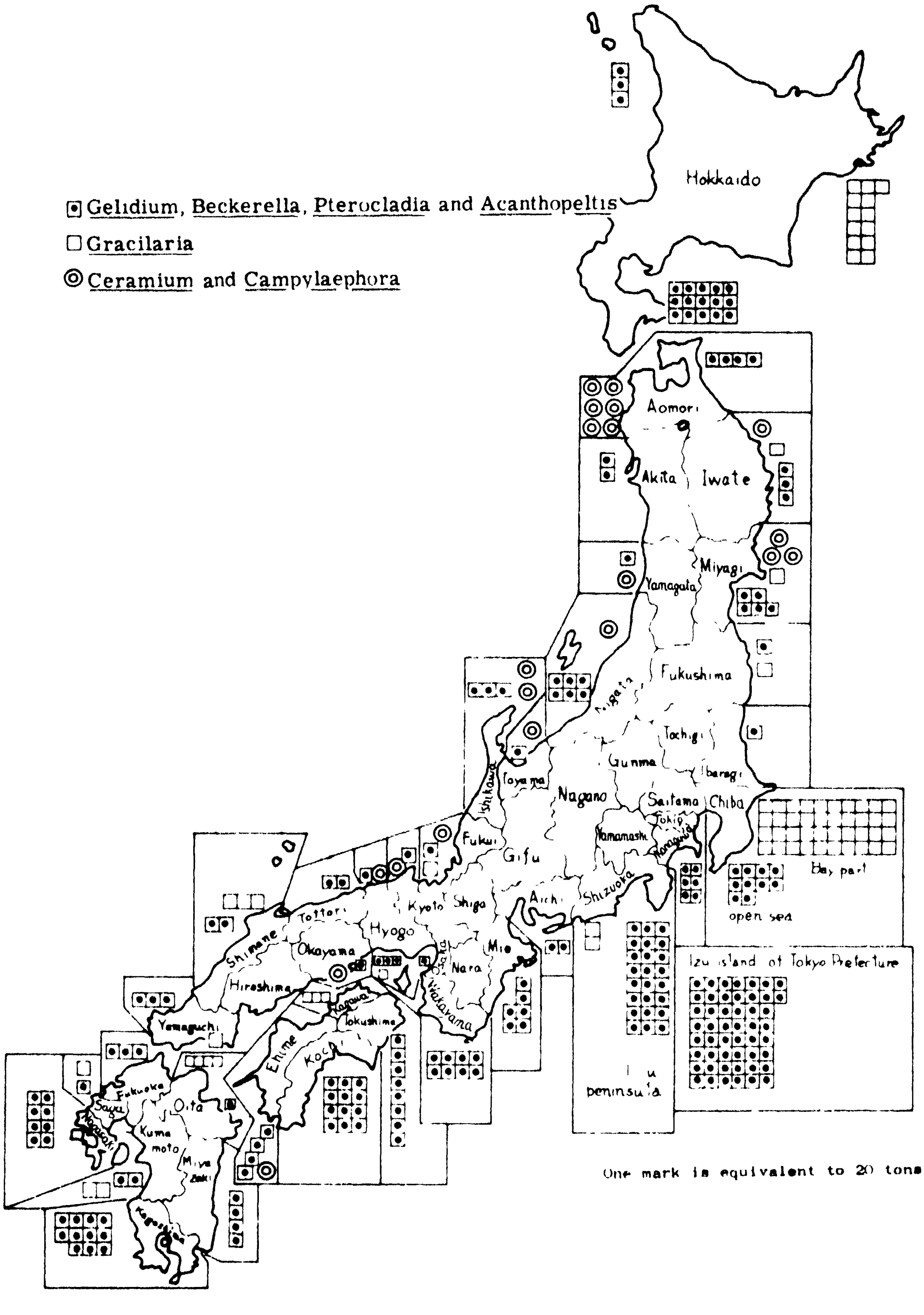


Figure 7. Distribution of agarophytes. (From Okazaki, 1971)

algae such as Enteromorpha - "aonori". In order to distinguish it from these other varieties the "nori" deriving from Porphyra can be specified as "asakusanori".

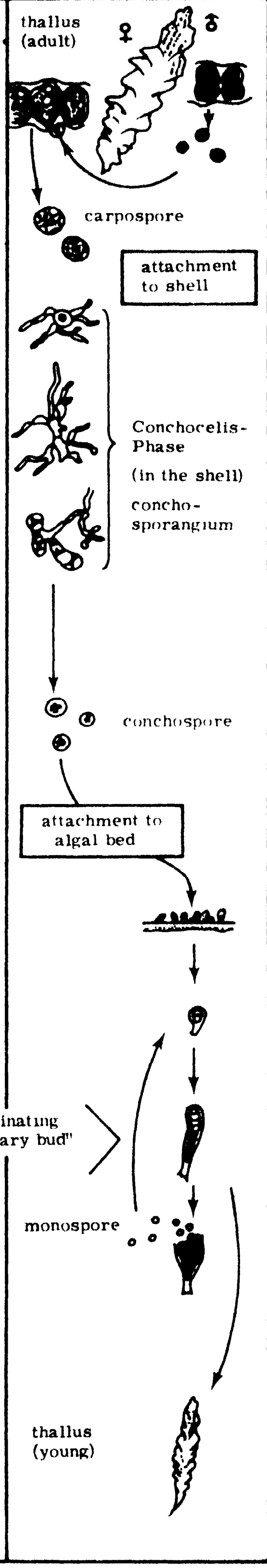
A number of species are cultivated along the temperate coasts of Japan, at present preferably in shallow waters in bays and between islands. Recently, however, an off-shore cultivation method has been developed. The dominating species in cultivation over both areas of inner and outer seas is P. yezoensis. Locally cultivated in the inner seas are P. tenere and P. kuniedai, while P. angusta is characteristic of the outer sea.

The plants are given an artificial substrate of nets or bamboo blinds. Leafless bamboo brushes or oak tree branches were once used. The introduction in the 1930s of horizontally hung nets meant a new epoch in Porphyra cultivation, as the whole sets can be moved to favourable ground and also vertically adjusted to the optimum level for the growing plants (Suto, 1966). There are now 8.7 million nets with a total area of 191 million m^2 and 171 000 blinds covering 18 million m^2. The yield of nori was estimated at 2 955 million sheets (Furukawa, 1972; all figures for 1968). The yield doubled for the following year, 1969; it was 5 592 million sheets, according to the Japanese Tariff Association, 1971. This increase is due to the enlargement of cultivating grounds through the expansion and popularization of the floating net method. (See also table below on harvest development.) Cultivation of nori in 1973 employed more than 60 000 families.

Culturing of Porphyra began in Tokyo Bay in 1736. In 1949 the mystery of the origin of the spores was solved in an account showing that the life cycle of Porphyra includes a shell-penetrating filamentous stage. In winter carpospores are released from the Porphyra plants, sink to the bottom and grow in mollusc shells. This sporophyte stage of various species had been described as a separate species and given the genus name Conchocelis. It is found all the year round, but first in September at shorter day length and lower temperatures it releases floating monospores, called "conchospores". Following this discovery, methods have been developed during the 1950s for artificial seeding of nets and blinds and for inhibiting or accelerating monospore liberation. The Conchocelis stage is cultivated in large quantities in oyster shells. From these the spores are released when temperature is lowered to 17–20°C, when the shells containing Conchocelis are exposed to 2 000 -3 000 lux for not more than 8–10 hours a day or to B-indol-potassium acetate in 1/20 000 - 1/10 000 solution. Half-dried young stages of 2–3 cm in length as well as plant remainders on recently harvested nets can be stored at -20°C until the next favourable season for setting the nets. It is estimated that in 1970 half the culture nets were refrigerated. The nets are often first placed in nutrient-rich estuaries and later moved towards the open sea. They must be changed according to tide water, should be exposed to the air for 3–4 hours a day in order to kill possible infections of other species, in particular green algae, and will have to be moved in case of pollution or unfavourable conditions. Optimum salinity is at a special gravity of 1 018–1 025 and optimum temperatures during seed collection are 20–25°C, during culture, 15–18°C, and during harvesting, 12–13°C. If necessary, 600 mg of fertilizer/m^2 is applied over 2–3 days in order to obtain a higher survival rate of young nori and to prevent the discoloration of grown nori (Furukawa, 1972). Fishermen who set nets or other carpospore collectors in the sea must pay royalty to the fishermen's association which has the fishery right of seed collecting in the sea (Okazaki, 1971). Figure 8 is a manual on conditions for artificial cultivation of Porphyra used at the Yamamoto Nori Research Laboratory.

The density of growing Porphyra has no importance. In a well grown state, the yield per 10 cm of hibi string was about 2 g whether there were 400 or 2000 individuals. The "law of constant final yield" proposed by Kida is applicable to the community of cultivated Porphyra (Yoshida, 1972).

During mild winters when the water remains warm, the yield of nori is very poor and the nori itself is attacked by a serious fungus disease. The only treatment known to be effective against this disease is the same as against competing species, i.e. to move the racks higher so that the nori will remain out of the water for about three hours a day (Suto, 1953).



INDUSTRIAL TECHNIQUE	SEASON IN NATURAL CONDITION	LIFE-CYCLE	CONDITIONS FOR ARTIFICIAL CULTIVATION
	April		FORMATION OF REPRODUCTIVE ORGANS (Length of Light Period) *long-day condition*
			GERMINATION OF CARPOSPORE *light intensity (Lux)*: 3000 / 1500 / 500 / 100 *number of perforations per 277mm² of oyster shell surface*: 149 / 138 / 109 / 91
			GROWTH OF CONCHOCELIS (Length of Light Period) *long-day condition 12~15 hrs* (Light Intensity) *higher than 500~800 Lux* (Water Temp.) *20~25°C (Opt.) (10~30°C)*
• *indoor cultivation*	August		FORMATION OF CONCHOSPORANGIUM (Length of Light Period) *short-day condition (shorter than 10 hrs)*
	September		PRODUCTION OF CONCHOSPORE (Length of Light Period) *8~10 hrs (shorter than 12 hrs)* (Light Intensity) *higher than 1500 Lux* *(being sensitive to light intensity of 20~40 Lux)* (Water Temp.) *18~21°C*
			LIBERATION OF CONCHOSPORE (Light Intensity) *low light intensity* (Occasion) *just after changing from dark to light period*
• *artificial seeding to algal bed (net)*			ATTACHMENT OF CONCHOSPORE TO ALGAL BED (Light Intensity) *higher than 800 Lux* (Occasion) *just after beginning of light period*
	November		GROWTH OF BUD (Length of Light Period) *long-day condition 8-10 hrs* (Light Intensity) *4 000~7000 Lux (light saturation is 20 000 Lux)* (Water Temp.) *15-18°C* *(15~18 hrs ———— 20±2°C)* *(12~15 hrs ———— 12±2°C)* *growth of bud and formation of reproductive organs promoted by long-day* *short-day used to delay fertility until bud is 2~3cm*
			PRODUCTION OF MONOSPORE (Length of Light Period) *independent* (Water Temp.) *higher than 15°C* (Occasion) *young bud of 2~3 weeks after germination* (if produced in young bud or developed thallus varies with species)
• *"cold storage technique"* • *"artificial atmospheric-exposuring technique"*			
• *"floating net method"*	December		GROWTH OF THALLUS (Length of Light Period) *8~10 hrs* (Water Temp.) *10~15°C*
• *harvest of thallus*	January		PROMOTION OF GROWTH *light period ——— high temperature* *dark period ——— low temperature*

Figure 8. Technique for indoor cultivation of Porphyra tenera and P. yezoensis. Edited by Yamamoto Nori Research Institute. By courtesy of T. Oohusa.

The development of the Japanese nori production can be attributed to major innovations in cultivation methods:

Year	Harvest 10^8 sheets	Cultivation technique innovations
1938–47	mean 8.6	Introduction of horizontal net bed
1957	15	
1958	17	
1959	18	Development of artificial seeding
1960	35	
1961	34	
1962	41	
1963	32	Development of cold storage technique
1964	45	
1965	30	
1966	37	
1967	35	Development of floating net method
1968	29	
1969	60	
1970	60	

(Yamamoto Nori Research Laboratory, 1971)

An estimate of the economics of nori production has been prepared, based on a medium-scale enterprise with 50 culture nets. There were 105 days of operation and 1 750 working hours a year. Gross income per culture season was U.S.$3 333 and the total expenditure per annum U.S.$1 660 (Furukawa, 1972).

Porphyra cultivation is described by Furukawa, 1972; Kurogi, 1963; Kurogi et al., 1971 (in Japanese); MacFarlane, 1968; Maruyama, 1966 (in Japanese); Okazaki, 1971; Subba Rao, 1965; Suto, 1966; Yamada, 1959. There have been numerous investigations into cultivation problems of Porphyra; further reference may be made to Chyung and Kim, 1966; Iwasaki and Matsudaira, 1958, Kurogi, 1961, 1972; Kurogi, Akiyama and Suto, 1962; Shimo and Nakatani, 1969.

5.5 Quantities and cultivation of Laminaria

The standing crop of the alginophytes along the entire coast of Hokkaido island is estimated at about 1.5 million t, exclusive of Laminaria and Undaria used as food, the production of which amounts to 150 000 t and 50 000 t respectively (according to Kinoshita, et al., 1947, quoted from Nakamura, 1968). The Laminaria fishery was about double until the loss, during the last war, of the Kuril and Sakhalin Islands where Laminaria was being fished in particularly large amounts. It is claimed that the U.S.S.R. does not utilize the Laminaria crop (Sundene, 1962).

To a large extent the natural growth of Laminaria is harvested in depths of 3–8 m with the help of various tools (Chapman, 1970; Sundene, 1962; Okazaki, 1971). The waters are too cold to allow collecting by divers.

As demand is greater than the supply, ways have been sought to increase the crop, such as planting of stones or concrete blocks, rope cultivation, digging the flat reefs when they are exposed at low water or dynamite blowing to create new rock bottoms (Laminaria does not attach well on rocks covered by crustaceous algae) and even blowing of shelves in steep mountains on a suitable depth. Methods of cultivation such as the long lines used in China are still in the experimental stage (Hasegawa, 1971, 1971a).

Stone-planting has been practised for about 300 years. Andesite is preferred as it best resists deterioration. Very big stones are necessary, usually between 600 and 700 kg, in order to stand firm against wave action on the open coasts, which are preferred by most

Laminarians. On sandy bottoms it is necessary to arrange the stones with consideration to water movements as they could otherwise easily be covered by moving sand.

Another reason for failure of stone-laying is the growth of species other than Laminarians on the stones, in particular coralline algae. Some years ago this phenomenon spread dangerously in Japan, not only on set out stones but also on the beds of naturally occurring Laminaria. The phenomenon is called "reef burn". A possible cause could be sudden influxes of fresh water, killing off other algae. Actually vast surfaces all around Japan are now covered by coralline algae, crustaceous as well as articulate. It has been noted that the initial development of the corallines is very rapid; for example, in Amphiroa ephaedra a spore gives 32 cells in 12 hours (Yamada, 1959).

There are some 15 genera and 50 species of Laminariales around Japan, 19 of these species belonging to the genus Laminaria. Of the species most utilized, L. japonica, L. religiosa, L. fragilis and L. ochotensis prefer a less cold water and L. angustata and L. diabolica a colder water.

The dried and packed products from Laminaria and related kelp genera are called "kombu". There is a large variety, all with different prefix names, some of which refer to the species used, others to size, form, mode of preparation (such as softening with acetic acid) or flavour additions. Details on preparation are given by Subba Rao (1965) and Okazaki (1971).

Eisenia, Ecklonia and Laminaria unsuitable for food are used as a raw material for sodium alginate. A good 30 000 t dry weight is put to this purpose, and also about 3 000 t of imported seaweeds, mainly Macrocystis pyrifera. The production is 1 264 t of sodium alginate and 161 t of propylene-glycol-ester of alginic acid (Okazaki, 1971).

5.6 Undaria

Of the total seaweed harvest, 11-15 percent is Undaria - "Wakame", of which 65-85 percent is harvested on the west side of Hokkaido and the northeast of Honshu. The product has the softest qualities among the brown seaweeds and is consumed in particular with miso-soup. In addition to stone-laying, bottom-cleaning with dynamite and rope-cultures, the growth of Undaria is also promoted by the removal of other seaweeds with tools or a specially designed machine (Okazaki, 1971).

Culture of Undaria may be done at any depth down to about 6 m, depending upon the clarity of the water. Since relatively high salinities and low temperatures are required, the most favourable locations are in fairly open areas. One bamboo raft, 36.6 m x 1.8 m with hanging ropes to a total of 100 m of string, produces about 1 t wet weight or 112.5 kg dry weight. On the Ojika peninsula there are 1 333 such rafts, which annually produce a total of 145 t of dry Undaria (Bardach, Ryther and McLarney, 1972).

5.7 Agaroids and agar production

Prior to the second world war, Japan enjoyed a world monopoly on agar by virtue of the development of the industry in the Orient and the abundant supply of agar-bearing seaweeds along Japanese coasts (Humm, 1947). As a consequence of trade stoppage during the war, the production of agar or agar substitutes was started in many parts of the world. The pre-war Japanese production was 2 260 t of agar of which 1 600 t was exported (1937 figures). After a bottom year of 275 t in 1946, production has steadily grown and since 1966 has surpassed pre-war figures, agar export however being much lower - a mere 875 t in 1970.

The main agaroid genera have already been enumerated with their respective average yields in dry weight according to Okazaki (1971) (p. 83). The total dry weight was given as 7 500 t. Statistics and Survey Department (1972) give the following fresh weight

figures: 1967, 21 300 t; 1968, 15 700 t; 1969, 17 000 t, with a value of 5.4, 3.5 and 5 million U.S. dollars respectively. In addition to this comes the raw agar import for 7.2, 2.3 and 2.5 million U.S. dollars respectively, the biggest constributors being Chile, Argentina and South Africa.

The Gelidium harvest derives from three species: G. amansii, 3 100 t, G. subcostatum, 620 t, and G. japonicum, 330 t. The total yields were: 3 800 t in 1966, and 4 925 t in 1967 of which as much as 1425 t came from the Shizuoka prefecture (Yamada, personal communication).

The manuring for Gelidium has been studied by Yamada (1967) and Yamada and Iwahashi (1964).

Agaroid distribution and harvesting, and in particular agar manufacture and uses, are described by Hoppe and Schmid (1969) and Okazaki (1971), who also give the Japanese export standard for colour, shape, uniformity, gel strength, moisture, etc. for different agar types.

5.8 Green algae

Monostroma commands the highest price of any seaweed in Japan. It is grown on nets suspended horizontally at intertidal levels near river mouths. Only 700 t was produced in 1973, a good per mille of the total seaweed production. The product is made into sheets like Porphyra. From 1955 to 1960 an average of 255 million sheets of such "aonori" were produced annually in Japan as compared to over 2 billion sheets of "asakusanori" (FAO, 1974; Bardach, Ryther and McLarney, 1972).

6. U.S.S.R.

On the Siberian coast of the Pacific some Laminaria beds (mainly L. japonica) have been estimated (quoted from Chapman, 1970):

NE Vladivostok, 1 200 km coastline	429 000 t
Strait of Tartary	552 000 t
Localities on Sea of Okhotsk	117 000 t
Localities on Kamchatka	784 000 t
Lesser Kuril Islands	70 000 t

Tokida (1954) investigated the marine algae of southern Sakhalin, where he found 182 species of which 75 are considered as useful in Japan, 46 as edible and 18 were actually used for articles of commerce. In 1935 the production exceeded a value of 1½ million yen.

Laminaria japonica, L. diabolica, L. cicorioides var. sachalinensis,
Arthrothamnus kurilensis and Kjellmaniella crassifolia gave 4 253 t of kombu
Ahnfeltia gave 143 t of kanten (agar)
Porphyra 6 t of nori
Iridophycus and Rhodoglossum 24 t of ginnanso, and
Gloiopeltis 8 t of funori

In order to preserve the stock the annual consumption of dry Ahnfeltia was limited to about 750 t dry weight corresponding to 10 percent of the presumed amount of biomass in Lake Tobuchi. Dried prepared Alaria was called sarumen, Gelidium was used only for local consumption, other species unutilized or underutilized at the time are also commented on. Halosaccion and Fucus were used as food by the Kamtschadales, as well as Alaria, Chordaria and Porphyra. For the cultivation of Porphyra 1.8 km^2 of artificial bottoms were created by pouring cement over the natural rocky reefs.

L. japonica is found only in the southern part of Sakhalin, and *L. sachalinensis* grows along all coasts. *Porphyra umbilicalis* is very abundant around the southernmost peninsula. It used to be collected directly from the rocks, not cultivated; grows during summer (J. Tokida, personal communication).

There are also estimates of the *Ahnfeltia* beds: in Peter the Great Bay near Vladivostok 104 000 t, Busse Lagoon on Sakhalin 24 000 t, and Ismen Bay in the Kurils 48 000 t. In Busse Lagoon the density ranges from 1–3 kg/m^2 and the weed forms a bed 20 cm thick at a depth of 4–4.5 m. *A. plicata* is the most important raw material for "Russian agar" or "Sakhalin agar".

Growth rate of commercial thickets of unattached *Ahnfeltia* depends on, in addition to environmental factors, the quantity of *Ahnfeltia* left on the bottom after collection or transplantation, how evenly they are distributed on the bottom and on fragmentation of the thallome in the case of artificial transplantation. In the Busse Lagoon the thickets are usually restored within two or three years under favourable conditions and within three or five years under less favourable conditions, the initial quantity of *Ahnfeltia* being 0.3–0.4 kg/m^2 (3 or 4 t per hectare) (Sarochan, 1966).

The seaweed ecology on the coasts of the Sea of Okhotsk is described by Vosshinskaya (1966) in a paper rich in data on biomass per area unit of the more important species. Among the areas described, the north coast is here taken as an example. It is indented but exposed, has intense surf and often dense fog, the tidal amplitude varies from 4.5 to 7.5 m (the littoral is subdivided into three horizons – I, II, III).

Seaweed quantities in g/m^2 on the north coast, Sea of Okhotsk

Unprotected sectors

I *Halosaccion glandiforme*, scattered 570, dense 3 850
I–II *Porphyra ochotensis* 815, slimy colonial diatoms 552
II *Halosaccion*
III *Lessonia laminarioides* 2 400, *Laminaria gurjanovae* 2 500, *L. subsimplex* 2 800

Protected sectors, littoral

I *Gloiopeltis capillaris* 812
II *Fucus evanescens* 250
III *F. evanescens* 4 500–6 100, *Halosaccion ramentaceum* 330, *H. microsporum* 500, *Rhodymenia ochotensis* 1 110, *Ulvaria splendens* 315, *Ulva lactuca* 380, *Porphyra amplissima* 318, *Petatonia fascia* 150, *P. zosterifolia*, *Chordaria flagelliformis*, *C. magellanica* 800, *Rhodomela tenuissima* 165, *R. larix* 110, *Halosaccion microsporum* 733, *Ceramium rubrum* 314, *Scytosiphon lomentarius* 160, *Antithamnion* 154, *Chorda filum*, *Hypophyllum middendorfii*, *Laingia pacifica* 600

Plant cover of depressions:

Ahnfeltia 600, *Chondrus crispus* 900, *Rhodymenia* 2 100, corallines 3 500, heterochordarias 2 500, irideas 3 000, polysiphonias 4 000

Sublittoral

Lessonia laminarioides, *Laminaria gurjanove*, *L. saccharina* 3 000–5 000
Alaria ochotensis, *A. dolichorhachis* 2 000–3 000, and from 4–5 m, *Laminaria digitata*, *L. subsimplex*, *L. ruprechtii*, *L. platymeris* 4 000–6 500, *Phyllariella ochotensis* 3 000
Soft bottoms, *Zostera marina* 2 000–2 500

This luxuriant cold-water flora with many useful species could evidently provide raw material for a seaweed industry similar to that existing on the Sea of Japan and on Sakhalin.

Floating algae are rare in the central Pacific but common along the coast of Asia. The greatest accumulations are noted at the junction area of currents off the coasts of Kamchatka, and the Commander, Aleutian, Kuril, Japanese and Philippine Islands, New Guinea and New Zealand. The number of floating plant species is more abundant than in the Atlantic and Indian Oceans. In some areas the mass of floating algae may be compared to the waters of the Sargasso Sea (Vozzhinskaya, 1966a).

Bardach, J.E., J.H. Ryther and W.O. McLarney, Aquaculture, the farming and husbandry of
1972 freshwater and marine organisms. New York, Wiley-Interscience, 868 p.

Boney, A.D., Aspects of the biology of the seaweeds of economic importance. Adv.Mar.
1965 Biol., 3:105-253

Chapman, V.J., Seaweeds and their uses. London, Methuen, 304 p.
1970

Cheng, T.H., Production of kelp - a major aspect of China's exploitation of the sea.
1968 Econ.Bot., 215-36

Chiu, B.T., Seaweeds of economic importance in South China. Proc.Int.Seaweed Symp., 2:
1956 171-2

__________, Seaweeds of economic importance in Hong Kong. Hong Kong Univ.Fish.J.,
1958 2:132-3

Chyung, M. and S.M. Kim, A study on the relation between laver (Porphyra tenera) product-
1966 ion and sea-water temperature. Proc.Pac.Sci.Congr., 11(7):21-21

Dawson, E.Y., Marine botany: an introduction. New York, Holt, Rinehart and Winston, 371 p.
1966

FAO, Yearbook of fishery statistics. Catches and landings 1970. FAO Yearb.Fish.Statist.,
1971 30:pag.var.

FAO, Yearbook of fishery statistics. Catches and landings 1973. FAO Yearb.Fish.Statist.,
1974 36:pag.var.

Furukawa, A., Present status of major Japanese marine aquaculture. In Coastal aquaculture
1972 in the Indo-Pacific region, edited T.V.R. Pillay, West Byfleet, Surrey, Fishing News (Books) Ltd., pp. 29-47

Hasegawa, J., Cultivation of Laminaria in Japan. Bull.Hokkaido Reg.Fish.Res.Lab., 37:46-8
1971

__________, Forced cultivation of Laminaria. Bull.Hokkaido Reg.Fish.Res.Lab., 37:49-52
1971a

Hayashida, F. and T. Sakurai, Algal flora and communities at Nochimune Suruga Bay.
1969 Jap.J.Ecol., 19(2):3-7

Hoffmann, C., 1938 Praktische Bedeutung der Meeresalgen. Kieler Meeresforsch., 3(1):165–232

Honda, N., 1970 Seaweed culture. In Survey of aquaculture industries. UNDP/FAO Fishery Advisory Services, Republic of Korea. Rome, FAO, FI:SF/KOR28 Tech.Rep., 3:49–69

Hoppe, H.A., 1966 Nahrungsmittel aus Meeresalgen. Bot.Mar., 9, Suppl:19–40

Hoppe, H.A. and O.J. Schmid, 1962 Meeresalgen als moderne Industrie-producte. Bot.Mar., 3 Suppl.

______ 1969 rcial products. Bot.Mar.Handb., 1:288–368

Humm, H.J., 1947 Agar – a pre-war Japanese monopoly. Econ.Bot., 1(3):317–29

Iversen, E.S., 1968 Farming the edge of the sea. London, Fishing News (Books) Ltd., 301 p.

Iwasaki, H. and C. Matsudaira, 1958 Culture of a laver, Porphyra tenera Kjellm. Bull.Jap.Soc. Sci.Fish., 24(6–7):398–401

Johnstone, H.W., 1966 The biological and economic importance of algae. 2. Tuatara, 14(1):30–63

Kang, J.W. and C.H. Park, 1969 Marine algae of Dok-Do (Liancourt Rocks) in the Sea of Japan. 1. Bull.Pusan Fish.Coll., 9(2):53–64

Kim, D.H., 1970 Economically important seaweeds in Chile. I. Gracilaria. Bot.Mar., 18:140–62

Kirby, R.H., 1953 Seaweeds in commerce. London, Her Majesty's Stationery Office, 157 p.

Kurogi, M., 1961 Species of cultivated Porphyras and their life histories (Study of the life history of Porphyra. 2). Bull.Tohoku Reg.Fish.Res.Lab., (18):1–115

______., 1963 Recent laver cultivation in Japan. Fish.News Int., 2(3):269–74

______ 1972 Systematics of Porphyra in Japan. In Contributions to the systematics of benthic marine algae of the North Pacific, edited by I.A. Abbot and M. Kurogi. Kobe, Japanese Society of Phycology, pp. 167–92

Kurogi, M., K. Akiyama and S. Sato, 1962 Influence of light on the growth and maturation of Conchocelis-thallus of Porphyra. 1. Effect of photoperiod on the formation of monosporangia and liberation of monospores. 2. Effect of different photoperiods on the growth and maturation of Conchocelis-thallus of P. tenera Kjellm. 3. Effects of photoperiod in different species. Bull.Tohoku Reg.Fish. Res.Lab., (2):121–56

Kurogi, M. et al., 1971 Advance in Porphyra culture. In Through culture, edited by T. Imai et al. Tokyo, Koseisha Koseikaku, pp. 1–79 (in Japanese)

MacFarlane, C.J., 1968 The cultivation of seaweeds in Japan and its possible application in the Atlantic Provinces of Canada. Proj.Rep.Ind.Dev.Serv.Dep.Fish.Can., (20):1–95

Maruyama, T., An efficient use of nori (Porphyra spp.) culturing ground at Nagai,
1966 Yokosuka. Bull.Tokai Reg.Fish.Res.Lab., 45:97-106 (in Japanese)

Mukai, H., The phytal animals on the thalli of Sargassum serratifolium in the Sargassum
1971 region, with reference to their seasonal fluctuations. Mar.Biol., 8:170-83

Nakamura, Y., The role of marine plants on radiation protection. In Guidelines to radio-
1968 logical health. Washington, D.C., U.S. Department of Health, Education and Welfare, pp. 112-5

Ohmi, H., The species of Gracilaria from Japan and adjacent waters. Mem.Fac.Fish.
1958 Hokkaido Univ., 6:1-66

Okamura, K., On the culture of Gracilaria confervoides. J.Fish.Inst., (Tokyo), 21 p.
1925

_______, Uses of algae in Japan. Proc.Pac.Sci.Congr., 5(4):3153-61
1933

Okazaki, A., Seaweeds and their uses in Japan. Tokay, University Press, 165 p.
1971

Oohusa, T., Cultivation of Asakusanori (laver) in Japan. Occas.Pap.Yamamoto Nori Res.
1971 Lab., 1971:2 p.

Sarochan, V.F., Biology, ecology and utilization of algae from the Soviet far east seas.
1966 Proc.Pac.Sci.Congr., 11(7):20-20[1]

Segawa, S. et al., The floating seaweeds of the sea to the west of Kyushu. Res.Oceanogr.
1961 Works Jap.Spec., (5):179-85

Shimo, S. and S. Nakatani, Studies on artificial mass culture of Porphyra tenera.
1969 1. Effect of light intensity and population density on the growth rate in Porphyra fronds. Bull.Jap.Soc.Sci.Fish., 35(6):524-32

Subba Rao, G.N., Use of seaweeds directly as human food. Reg.Stud.IPFC, (2):32 p.
1965

Statistics and Survey Dept., Ministry of Agriculture and Forestry, Government of Japan,
1972 Fisheries statistics of Japan 1969. Tokyo, 59 p.

Sundene, O., Dyrking og anvendelse av tang og tare i Japan. Blyttia, 20(3):105-21,
1962 (4):145-67

Suto, S., Seaweed production and phycological research in Japan. Proc.Int.Seaweed Symp.,
1953 1:96-99

_______, "Nori" (Porphyra) cultivation in Japan. Proc.Pac.Sci.Congr., 11(7):22
1966

Tanaka, T., Marine algal flora on the barrier reef around Yoron Island, southern end of
1964 Japan. Proc.Int.Seaweed Symp., 4:276-9

Taniguti, M., Phytosociological study of marine algae in Japan. Tokyo, Inoue & Co., 129 p.
1962

Tanikawa, E., Marine products in Japan: size, technology and research.
1971 Tokyo, Koseisha Koseikaku, 507 p.

Tokida, J., The marine algae of southern Sakhalin. Mem.Fac.Fish., Hokkaido Univ., 2(1)
1954

Tseng, C.K., Gloiopeltis and other seaweeds of Amoy, China. Lignan Sci.J., 12:43-63
1933

_____, Marine products of Kiachow Bay. Science, Sci.Soc.China, 17:1931-47
1933a

_____ ic seaweeds of Kwantung Province, China. Lignan Sci.J., 14:93-104
1935

_____, Utilization of seaweeds. Sci.Mon., 59:37-46
1944

Tseng, C.K. and C.S. Chang, Economic marine algal flora of the Yellow Sea and E. China
1959 Sea. Hai-Yang Yu Hu-chao, 2:43-52

Tseng, C.K. et al., On the cultivation of haitai (Laminaria japonica Aresch.) by summering
1955 young sporophytes at low temperature. Acta Bot.Sinica, 4(3):255-64

_____, Studies on fertilizer application in the cultivation of haitai (Laminaria
1955a japonica Aresch.). Acta Bot.Sinica, 4(4):375-92

_____, The effect of temperature on the growth and development of haitai (Laminaria
1957 japonica Aresch.). Acta Bot.Sinica, 6(2):103-30

Vozzhinskaya, V.B., Ecology and distribution of algae on the continental coast of the Sea
1966 of Okhotsk. Tr.Inst.Okeanol., 81:153-75 (in Russian). Issued also as Transl. U.S. Naval Oceanogr.Off., (450)(1971)

_____, Notes on free-floating plants in the Pacific. Proc.Pac.Sci.Congr., 11(7):
1966a 10-101

Yamada, Y., Sur la culture des algues sur les fonds de sable ou de vase au Japon. In
1959 Colloques Internationaux du Centre National de la Recherche Scientifique, Dinard, 20-28 September 1957. Paris, Centre National de la Recherche Scientifique, vol. 81:251-62

Yamada, N., Studies on the manuring for Gelidium. Res.Rep.Prefect.Fish.Exp.Stn.,
1967 Shizuoka, (32) (in Japanese)

Yamada, N. and Y. Iwahashi, Studies on the manure for seaweeds. 4. On the manuring for
1964 yellowed Gelidium bed. Bull.Jap.Soc.Sci.Fish., 30(12):986-92 (in Japanese, with English abstract)

Yamada, Y. and T. Tanaka, The marine algae from the Island of Yonakum. Sci.Pap.Inst.
1944 Algol.Res., Hokkaido Imp.Univ., 2(1):53-86

Yoshida, T., Relations between the density of individuals and the final yield in the
1972 cultivated Porphyra. Bull.Tohoku Reg.Fish.Res.Lab., (32):89-94 (in Japanese, with English summary)

FISHING AREA 67 : NORTHEAST PACIFIC

The whole area is dominated by kelp species. The giant kelps Macrocystis and Nereocystis are the most important from the point of view of utilization, but a total of 32 species of Laminariales fringe the coasts.

A survey of kelp quantities of the U.S. Pacific coasts was conducted in 1911-13, when there was a demand for potash (Rigg, 1912; Cameron, 1915). Acetone and calcium acetate were also derived from Macrocystis, as well as iodine and a bleaching agent called "kelpchar". The following data refer to productivity of kelp beds within the U.S. part of the Northeast Pacific fishing area as determined 60 years ago:

	Area of kelp beds (km^2)	Tons fresh weight
Western Alaska	46.5	3 567 000
Southeast Alaska, surveyed area	183	7 833 000
Southeast Alaska, estimated additional	183	7 833 000
Puget Sound	13	520 000

The survey accounts for three species only: Macrocystis (actually two species confused at that time), Nereocystis luetkeana and Alaria fistulosa. In the case of Macrocystis, which is a perennial, determination of the yield of such beds was based on two cuttings per annum. The southeastern Alaska survey was incomplete and covered perhaps less than half of the region. The figures obtained in the surveyed area therefore were repeated in order to reach a total for Alaska, as it was estimated that the region not surveyed supported a similar weight. Tseng (1947), concluding from quantities harvested in Southern California, believes that area could produce slightly more than 5 percent of the 1911-13 estimate and assumes the same reduction should be made of all figures in the Pacific kelp beds survey. Later authors, however, seem to disregard Tseng's objections and adopt the figures of Cameron and his collaborators. There are also some recent up-datings; it seems dangerous, however, to take over data as there are so many confusing changes (the data for "productivity" are re-termed "standing crop" without taking into account that Macrocystis figures are derived from two harvests, the doubling of Alaska figures is left out, etc.) that possibly well founded amendments of the 1911-13 figures are hard to sort out.

All edible seaweeds used in the U.S.A. are now imported from the Far East. Prices of these products, which come from countries in which the plants are already in short supply, are very high. The Northwest Fisheries Center is now exploring the possibility of culturing marine algae, and whether suitable quantities can be produced to support an industry. A preliminary study of Porphyra showed rapid growth, substantial bulk and the possibility of spacing several species over a year-round growing season. P. miniata grows in the spring and reaches a length of over 4 m; P. perforata, a summer species, reaches a length of over 2 m. One stand of 460 m^2 at Manchester Experiment Station near Seattle produced over 680 kg wet weight (Northwest Fisheries Center, 1973).

2. Canada - British Columbia

The British Columbia Research Council and the Fisheries Research Board did a Canadian kelp resource inventory in 1946 using methods similar to those employed in the survey of U.S. kelp resources. This survey covered only readily accessible areas along the north mainland coast, the northeast coast of Vancouver Island and the area between Vancouver Island and the mainland coast south to the U.S. boundary. The Queen Charlotte Islands and the west coast of Vancouver Island were not surveyed. The quantities of readily accessible kelp were estimated at 22 500 t of Macrocystis and 370 000 t of Nereocystis

based on one harvest per year. These estimates are regarded as on the low side. Scagel's (1948) more detailed investigation in the Hardy Bay area suggested that the figure for *Macrocystis* was perhaps half or one-third of the true value because of the unfavourable stage of tide at which it had been necessary previously to examine many of the beds of floating kelp. According to this amended estimate, Scagel (1961) arrived at 750 000 to 1 000 000 t of readily accessible floating kelps available annually. If *Laminaria*, *Alaria* and *Hedophyllum* were added, the total algin sources available in British Columbia would reach at least 1 500 000 t annually. Other estimates have suggested that 3 to 20 times this amount is to be expected (Hutchinson, 1953).

In the period 1965–67 a private firm inventoried the kelp resources of the northwest and northeast coasts of Vancouver Island. Their estimates were based not only on the area and average density of accessible kelp but also took into account only that portion of the thallus within 1.5 m of the water surface at zero tide. In this way their estimates indicate the tonnage actually available to a commercial harvester. Accordingly they found 457 081 t of commercially available *Nereocystis* along the northwest coast of Vancouver Island and 82 007 t of *Nereocystis* and 21 924 t of *Macrocystis* along the northeast coast.

Through the medium of a cost-sharing agreement, the Federal Fisheries and Marine Service and the Provincial Marine Resources Branch initiated a series of marine plant inventories in 1972. To date the following inventories have been completed:

1. North coast, Queen Charlotte Islands	*Macrocystis*	75 417 t	(total biomass)
	Nereocystis	54 089 t	" "
	Laminariales	13 931 t	" "
2. Skidegate and Cumshewa Inlets, Queen Charlotte Islands	*Macrocystis*	24 240 t	" "
	Laminariales	5 486 t	" "
3. Central Georgia Strait	*Iridaea*	1 650 t	(available)

Collating inventory data from surveys which employed different techniques is a risky business at the best of times. Nevertheless it would appear that the British Columbia kelp resources total approximately 1 000 000 t. The *Iridaea* resources, while quantitatively much smaller, are located in dense beds in highly accessible areas closer to shipping and marketing centres.

In addition, inventories of kelp resources in the Port Hardy–Malcolm Island area along the northeast coast of Vancouver Island and of *Iridaea* resources in the northern section of Georgia Strait were made in the summer of 1974 (data not yet available at time of writing). Future inventories of kelp stocks are planned for the whole north mainland coast, in areas of the Queen Charlotte Islands not yet surveyed, and on the west coast of Vancouver Island. Agarophyte surveys will also soon be under way as will an inventory of *Sargassum muticum* in Georgia Strait (provided that preliminary investigations of its chemical composition indicate its suitability for commercial utilization).

One strong feature of recent British Columbia seaweed inventories is that standard inventory methods have been or are being developed. These standard methods employ large-scale aerial photography supported by ground truth sampling and have been developed to provide a basis for comparison of data collected in different areas and in the same area over a period of time.

3. Northeast Pacific – general

Nereocystis luetkeana is dominating in quantities and is recorded for 78–94 percent of the floating kelp beds in Oregon, Washington, British Columbia and southeast Alaska. In western Alaska there is 55 percent *Nereocystis*, 12 percent *Alaria* and 33 percent of a mixture of the two. The total distribution of *Nereocystis* almost coincides with the present

delineation of the Northeast Pacific. To the west it reaches the Aleutian Island of Unalaska at 167°W. To the south it approaches 35°N in California.

Nereocystis or bull kelp is essentially an annual plant. Nevertheless, it reaches a stipe length of 30 m, may grow in waters down to 18 m and may weigh 11 kg or more. It is most useful to navigators as parts of the thallus float on the surface indicating shallows and off-shore rocky reefs.

Macrocystis integrifolia accounts for 6-18 percent of the beds within its area of distribution, which is smaller than that of Nereocystis. In western Alaska it is not included at all in the quantities recorded and the westernmost finding is at Kodiak Island 159°W. In spite of being found in smaller quantities, Macrocystis is economically perhaps the most important seaweed in the area, as it is the most demanded for the algin industry. Macrocystis is perennial from the holdfast. It is restricted to areas near the open ocean. In British Columbia it occurs usually inside an outer protecting fringe of Nereocystis and grows from zero tide level down to 9 m. Near Deer Island most of the Macrocystis occurs in less than 4 m of water at zero tide, and 50 percent of it in less than 2 m. The plants may exceed 30 m and weigh 45 kg. Under favourable conditions major stipes grow more than 5 cm a day. The maximum elongation recorded was an average of 7.8 cm a day for a period of 29 days. For practical purposes a tonnage of 4.9 kg/m^2 was estimated when the surface coverage was approximately 30-50 percent.

These two giant kelp species have been particularly successful in North American industry as they grow sufficiently deep to allow collecting with mechanical harvesters cutting the stipes at a depth of 1.2 m and hoisting the kelp on board by means of a chain elevator (Tseng, 1947; Scagel, 1948, 1961; Druehl, 1970).

Looking for a total, we find that of Cameron's estimate, 20 000 000 t fall within the U.S. parts of the Northeast Pacific. If we extend Tseng's conclusion from his California check of actual harvests and reduce to 5 percent, there might be only 1 000 000 t of Macrocystis and Nereocystis to harvest annually. For a guess within this span we assume that Scagel's figures are representative. Extrapolating from British Columbia the whole area of the Northeast Pacific might have about 4 million t of giant kelp.

Among other kelp species there are in particular three which could be regarded as potential resources in British Columbia even if none of them constitutes a commercial quantity in itself.

Hedophyllum sessile are metre-high, much-frilled blades growing at 1-2 m above zero tide level just below the fringe of Fucus, where it has to be hand-collected. Some growth continues after the top portion of the plant has been cut off, provided the holdfast and a basal portion of the blade are left intact. Alaria marginata grows from 1 m above down to zero tide level, and occurs in fairly extensive patches which are easily accessible at low tide. They also require hand-harvesting. It may be possible to cut off the upper portion of these plants, leaving the basal portion bearing the sporophylls, and thus prevent damage to the reproductive structures of the plants. Laminaria saccharina grows from zero tide level downwards several metres. Reproduction takes place in the main portion of the blade, which might be able to regenerate from the base. They could be hand-harvested or taken with rakes in deeper water. Most harvesting methods, however, would tear loose the whole plant and probably bring in small rocks and boulders as well in many cases, which could damage cutters (Scagel, 1948).

If we want to add these and other kelp species to the total for alginophytes in the Northeast Pacific, we could also follow Scagel (1961) in British Columbia and assume they reach 50-100 percent of the quantities of the giant kelps, say some 3 million tons. As Macrocystis disappears in western Alaska, Laminaria, and in particular Alaria, flourish in northern latitudes, such an assumption would be on the low side.

The distribution of Laminariales in the Northeast Pacific in a wider sense from Baja California to the westernmost Aleutian Islands was studied by Druehl (1970) (see Fig. 9). Richest in species is the Vancouver Island region with 28 species. Five species have their northern end points in this region, eight their southern. In the Gulf of Alaska, 22 species are recorded of which five continue no further southeast and two no further southwest. From the Alaska peninsula to the Aleutian Islands the number of species goes down from 17 to 13.

Other algae than kelp are also plentiful. "Gracilaria and Gracilariopsis are fairly abundant in British Columbia, especially along the southeast coast of Vancouver Island. Under favourable conditions they grow rapidly and reach a remarkable length. Other species of agarophytes are also known in these waters. As yet abundance and distribution have not been determined comprehensively for any agarophyte." (Scagel, 1961). Agardhiella, Ahnfeltia, Gelidium, Gigartina, Gloiopeltis, Iridaea, Rhodoglossum and Rhodymenia could be mentioned as other examples.

Iridaea cordata and Gigartina exasperata have received a good deal of attention in British Columbia and in the Puget Sound area of Washington. In British Columbia, Austin et al. (1973) and Austin and Adams (1974) have developed a method for inventorying Iridaea, applied the method and determined its accuracy, studied Iridaea's seasonal growth and reproductive cycles, studied the effects of harvesting on regrowth and begun studies on cultivation. Fralich (1971) has studied the effect of harvesting Iridaea on the algal community in northern Washington. Waaland (1973), working in the same area, has determined some of the optimal environmental parameters for Iridaea and Gigartina.

Washington has a similar marine flora, as investigated in Puget Sound (Rigg, 1912; Neushul, 1967) and Hood Canal (Phillips and Fleenor, 1970).

REFERENCES

Austin, A.A. and R. Adams, 1974 Red algal resource studies in Canadian Pacific water. Annual report 1973. Submitted to Federal Minister of Fisheries and the Provincial Minister of Recreation and Conservation, 256 p.

Austin, A.A., et al., 1973 Development of a method for surveying red algal resources in Canadian Pacific water. Annual Report 1972. Submitted to Federal Minister of Fisheries and the Provincial Minister of Recreation and Conservation, 172 p.

Cameron, F.K., 1915 Potash from kelp. Rep.U.S.Dep.Agric., (100):122 p.

Druehl, L.D., 1970 The pattern of Laminariales distribution in the Northeast Pacific. Phycologia, 9(3/4):237-47

Fralich, J., 1971 The effect of harvesting Iridaea on a sublittoral marine plant community in Washington. Thesis, Western Washington State College, 57 p.

Hutchinson, A.H., 1953 Marine plants of economic importance of the Canadian Pacific coastal waters. Proc.Pac.Sci.Congr., 7(5):62-6

Neushul, M., 1967 Studies of subtidal marine vegetation in western Washington. Ecology, 48(1): 83-94

Northwest Fisheries Center, 1973 Seaweeds, future crops for the Pacific northwest? Mon.Rep. Northwest Fish.Cent., October issue:1-5

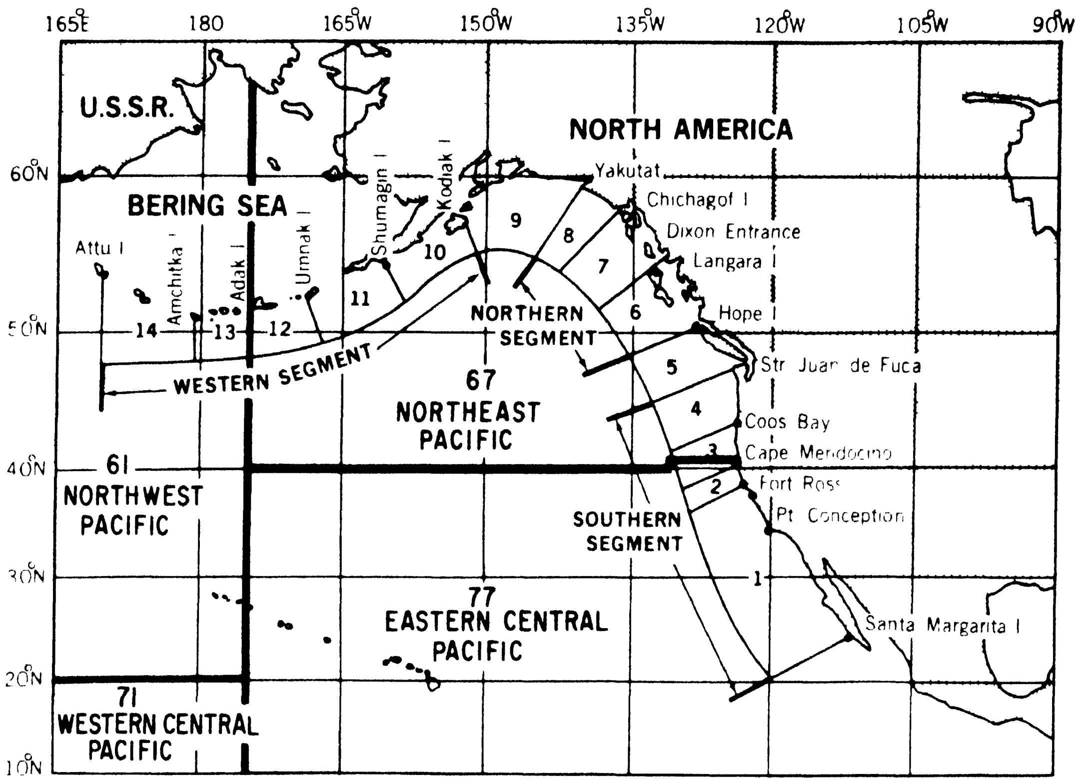


Figure 9. Distribution of Laminariales in the Northeast Pacific. There are three distinct coastal floras and a number of transitional regions (odd numbered) and non-transitional regions (even numbered). Limits of Fishing Areas for statistical purposes entered. (After Druehl, 1970)

Phillips, R.C. and B. Fleenor, Investigations of the benthic marine flora of Hood Canal,
1970 Washington. Pac.Sci., 24(2):275–81

Rigg, G.B., Ecological and economic notes on Puget Sound kelps. In A preliminary report
1912 on the fertilizer resources of the United States, edited by F.K. Cameron.
Washington, D.C., U.S. Senate, Doc. No. 190, 62nd Congress, 2nd Session, 290 p

Scagel, R.F., An investigation on marine plants near Hardy Bay, B.C. Rep.B.C.Dep.Fish.,
1948 (1):70 p.

__________, Marine plant resources of British Columbia. Bull.Fish.Res.Board Can., (127
1961 39 p.

Tseng, C.K., Seaweed resources of North America and their utilization. Econ.Bot., 1(1):
1947 69–97

Waaland, J.R., Experimental studies on the marine algae Iridaea and Gigartina. J.Exp.
1973 Mar.Biol.Ecol., 11(1):71–80

FISHING AREA 71 : WESTERN CENTRAL PACIFIC

This region is well known for its extensive use of algae for human consumption. Probably it comes next to the Northwest Pacific in this respect. "Nevertheless, it should be remarked that the utilization of marine algae as human food, particularly in the Malay Peninsula and in Indonesia, seems nowadays by no means as general as one would suppose, when reading the earlier authors like Rumphins and von Martens" (Zaneveld, 1955).

1. Indonesia

In 1971, 2 300 t were harvested. In 1940, 1 300 t raw seaweed were exported (Kirby, 1953).

The human consumption of seaweeds is widespread. They are particularly used when the rice harvest is bad or when the prices have risen. Subba Rao (1965) mentions more than 20 species, how and where they are used. The green algae *Caulerpa*, *Chaetomorpha*, *Codium* and *Ulva* are used raw or in soups or gelatine-like sweets (marshmallows). Brown algae such as *Dictyota*, *Padina*, *Sargassum* and *Turbinaria* are eaten raw or cooked with coconut milk, pickled or preserved by smoke-drying. The red algae, especially *Eucheuma muricatum* but also *Acantophora*, *Corallopsis*, *Gelidium*, *Gracilaria*, *Hypnea* and *Sarcodia*, are either eaten fresh or prepared in similar ways to the brown algae or the jellies are extracted for various kinds of gelatines. When extraction is intended, the first step might be that the seaweeds are dried, bleached and stored.

The agar, funorin or algin content and quality of samples from a number of species of possible commercial value have been investigated by the Laboratory for Chemical Research in Bogor on western Java (Eisses, 1952). *Gracilaria lichenoides* was at that time by far the most important raw material for the small Indonesian agar factories. *Gelidium rigidum* gave stronger gels but seems to be found in smaller quantities. *Hypnea musciformis hippuroides* is also a potential agar source. *Eucheuma* species form the greatest part of the seaweeds exported from Indonesia under the name of raw agar.

For these species there is a high commercial demand and a sure export market. Despite the abundance of natural resources in the eastern part of Indonesia (Lesser Sunda Islands) the supplies lag behind, and Soerjodinote (1969) suggests cultivation of *Eucheuma spinosum* and *E. edule* on selected localities in the western Java Sea. An interesting part of his paper is a detailed cost-profit calculation.

Hypnea musciformis is used as an antihelminthic.

2. Malaysia

"Agar-agar" is a Malay word for those seaweeds, like *Gracilaria*, which yield a gelatinous jelly used for making sweetmeats. Seaweeds have old traditions in Malayan cooking. They are used fresh or cooked or for jellied sweets. Subba Rao (1965) mentions *Caulerpa*, *Codium*, *Enteromorpha*, *Ulva*, *Sargassum*, *Turbinaria* and *Gracilaria* species. *Caulerpa* has a piquant taste and is used as a relish. The seaweeds may also be dried, then boiled, strained, sugar added and re-boiled with an egg which brings scum and clears the final product. Weeds are also used in the Malay delicacy "kerabu", described by Kirby (1953). According to Zaneveld (1949), *Sargassum* species occur principally in the Malayan archipelago.

3. Brunei

No information available.

4. Singapore

A certain seaweed commerce is centered in Singapore, but the local flora is rather poor under the influence of pollution and dilution. *Ulva* has a popular local use by Chinese market gardeners as a pig and duck food (H.M. Burkhill, personal communication). *Eucheuma* has been produced, but the beds suffer from overharvesting (Parker, 1974).

5. Thailand

The Thai west coast flora is extremely thin and poor in species. Many areas render little or no growth. Controlling factors are sharp shifts in salinity following the monsoon period, calm, unmoving waters with lack of aeration, silting, heat and pollution from tin mines. Grazing may play a role, but to what extent is unknown (Egerod, 1974, 1975). On the east coast larger specimens are found. Porphyra is seen on many shores but it is not collected. A species similar to Furcellaria, however, is actually gathered. The algae are used in Thai cooking and the amount of algae imported from China and Japan is considerable (Vagn Hansen, Phuket Marine Biological Center, personal communication).

6. Cambodia

No information on use or quantities.

7. Republic of Viet-Nam

The species most frequently found and probably the most abundant and used is Gracilaria lichenoides, the "Ceylon agar". The species of Eucheuma, Gloiopeltis and Gymnogongrus available do not seem to leave good gels (Lami, 1953).

Agar freshly extracted from seaweeds is eaten mixed with rice. On the southern coast of Viet-Nam the red alga Griffthsia corallina is eaten with sugar after it has been bleached, compressed and cut up (Subba Rao, 1965). Gracilaria verrucosa, Gigartina and the brown algae Sargassum cinctum and Cnoospora fastigiata are also eaten by fishermen and sold in the markets (Kirby, 1953).

Some species of Sargassum are said to be utilised for animal feed, especially for pigs. Lami has also observed remarkable results by feeding horses suffering from lymphangites with Hizikia fusiformis.

Pham Hoang Ho (1961) has studied the algal populations of rocky littorals.

8. Democratic Republic of Viet-Nam

No information available.

9. Philippines

The coastlines of the 7 000 islands of the Philippines do, in general, provide good substrata for seaweeds. A very great part of its 35 million inhabitants live close enough to the sea to have access to seaweeds, which also form a part of their diet. Velasquez (1953) states that "it is quite noticeable that the people living in the coastal regions are more industrious and healthier than those living inland".

Eucheuma is commonly offered for sale in the market. It is eaten raw as salad. Commercially it is the most important of the seaweeds as a carrageenin raw material and has been exported to Japan and the U.S.A. The biggest natural grounds and best areas for farming are the wide shallow areas in the Sulu Archipelago. Due to poor conservation practices by gatherers, who take all the available seaweeds of the area and leave nothing to grow, the yearly export of this product has been diminishing for the past five years (Caces-Borja, 1973). Therefore Eucheuma biology has been studied and cultivation introduced. E. cottonii, E. spinosum and E. striatum are generally found on shallow reef flats and in lagoons at a water depth of less than 2 m at high tide. Best cultivation results were obtained with plants suspended 0.6 m above the bottom on nylon lines attached to stakes driven into the sand. They thrive best in salinities above 34 per mille, in considerable wave action or currents. Excessive light might damage thalli and induce premature "ageing". For example, Eucheuma planted over light-reflecting sandy bottoms has frequently failed. Fertilizing cultivated areas may dramatically improve growth rates. E. spinosum test plant growth rates increased by 40-50 percent when 4.8 kg of ammonium sulphate was applied to the test area over a ten-day period. However, fertilising is not yet economical.

When plants reach an average size of 800 g about two months after planting, they are ready to be pruned back to 200 g again. This method eliminates the need to replant. In 1973 Filipino farmers had established 86 Eucheuma farms in the Sulu Archipelago. These farms contained over half a million plants. It is estimated that cultivation will account for more than half of the Philippine commercial production by 1975.

Productivity was estimated at 13 t dry weight per hectare and year at a pilot farm in Tapaan Island, where the growth rate of cultivated Eucheuma was 2 percent per day. This yield compares favourably with yields reported for the most productive land and marine crops. Nevertheless Doty (1973), on results of smaller scale farms in other parts of the Philippines, estimates that 30 t per hectare and year may be expected. The difference is found in growth rate; in other areas it has frequently been more than twice that of the Tapaan pilot plant.

Considering that a farming family can effectively tend one to three modules and assuming the lower of these productivity assessments, 13 t/hectare, we can calculate an expected return. If two modules are farmed, annual production should be about 6.6 t dry weight or a monthly harvest of 550 kg, yielding an annual net income about six times the current annual salary of an agricultural worker earning a minimum wage (Parker, 1974).

Porphyra, here called "gamet", has been cultivated for a long time in north Luzon. Long bamboo poles with branching ends are erected close together in rows along the shore. After 4–6 months the algae can be collected by hand during low tide. When partially dried, it is pressed and sold in the market or bartered for an equivalent amount of rice. "Gamet" is shipped to interior municipalities and barrios where it is relished as food.

In south Luzon the green algae Enteromorpha intestinalis, Cladophora sp., and Chaetomorpha aerea serve as food for milkfish in ponds, giving the fish a much better taste. They are grown on twigs and branches of mangrove trees set in the water. Several phaeophyceae are used as fertilizers (Velasquez, 1953; Villaluz, 1949).

The quantity of seaweeds gathered and consumed as human food is not assessed. Seaweeds are sold fresh in the markets in coastal towns. Caulerpa racemosa, which is planted in large containers, has to be sold within a few hours after collection, otherwise it will shrink and deteriorate. Recipes for the preparation of 12 species are given by Bersamin et al. (1961); Subba Rao (1965) gives three recipes developed by the Philippines Bureau of Fisheries. The most frequently used species belong to the genera Gracilaria, Hypnea, Caulerpa and Sargassum. Laurencia papillosa is also very popular as a vegetable. The methods of preparation for 19 species, which are eaten fresh, dried or cooked in Ilocos Norte, are indicated by Velasquez (1972), their distribution and occurrence by Galutira and Velasquez (1963).

Seaweed protein for animal feed has been evaluated (Bersamin, Banania and Rustia, 1969). Tons of Gracilaria are harvested every day during the dry season to supplement the fish pond algae, the growth of which is stunted during this period due to high salinity. The utilization of seaweeds as fish food enables fish pond owners to continue the cultivation of fish unhampered (Sulit, Navarro and San Juan, 1953).

Because of the very rich resources of Gracilaria verrucosa from January to June, especially along the shallow shores of Manila Bay, Sulit, Salcedo and Panganiban (1955) undertook a study of its properties and preparation. Here an estimate of quantities is given: at the peak season no less than 1 000 tiklis (a round basket taking 35 kg of seaweed) is harvested daily. Gracilaria is the main source of agar-agar, or gulaman. There is a growing demand for Gracilaria and possible methods for its cultivation are being studied (Caces-Borja, 1973).

Discharge of pollutants from an oil refinery has caused poor growth of algae in the Bataan area west of Manila as compared to Batangas south of the capital.

Sargassum, Hydroclathrus, Eucheuma, Gracilaria and Halymenia species are being studied for their chemical and nutritive values (Velasquez et al., 1971).

The Philippine seaweed harvest dwindled from a peak of 1 100 t in 1966 to 318 t in 1970; the export from 805 t dry weight in 1966 to 264 t in 1968, of which 229 t went to the U.S.A. The decrease in harvests indicated an over-exploitation of the natural Euch resources, so that culture had to be started. In 1972 exports were up to 570 t (Caces-Borja, 1973).

10. Micronesia and Melanesia

There is no information on quantities. Seaweeds are eaten and prepared in similar ways to Indonesia.

Phycological literature referring to the Caroline and Mariana Islands, Wake Island, and the Marshall, Gilbert and Ellis Islands is listed in Tsuda (1966). A systematic account of the algae of the Caroline Islands is given by Trono (1968, 1969).

11. New Guinea

There is no information from any part.

12. Australia (Arnhem Land, Gulf of Carpentaria and Great Barrier Reef area)

No information on quantities.

REF

Bersamin, S.V., R.B. Banania and R. Rustia, Protein from seaweeds for animal feed
1969 substitutes. Philipp.J.Sci., 96(2):159-75

Bersamin, S.V. et al., Some seaweeds consumed fresh in the Philippines. Tech.Pap.IPFC,
1961 (11):7 p. Issued also as Proc.IPFC, 9:115-9 (1962)

Caces-Borja, P., The seaweed industry of the Philippines. Paper presented to Southeast
1973 Asian Fisheries Development Center Technical Seminar on South China Sea Fisheries Resources, 21-25 May 1973. Bangkok, 7 p.

Doty, M.S., Eucheuma farming for carrageenan. Sea Grant Advis.Rep., (UNIHI-SEAGRANT-AR-
1973 73-02):24 p.

Egerod, L., Report of the marine algae collected on the fifth Thai-Danish expedition of
1974 1966, Chlorophyceae and Phaeophyceae. Bot.Mar., 17:130-57

__________, Marine algae of the Andaman Sea coast of Thailand: Chlorophyceae.
1975 Bot.Mar., 18:41-66

Eisses, J., The research of gelatinous substances in Indonesian seaweeds at the
1952 laboratory for chemical research, Bogor. J.Sci.Res., 1(2):44-9

Galutira, E.C. and G.T. Velasquez, Taxonomy, distribution and seasonal occurrence of
1963 edible marine algae in Ilocos Norte, Philippines. Philipp.J.Sci., 92(4): 483-522

Kirby, R.H., Seaweeds in commerce. London, HMSO, 157 p.
1953

Lami, R., Pour une utilisation industrielle des algues marines d'Indo-Chine. Proc.Pac.
1953 Sci.Congr., 7(5):80-3

Parker, H.S., The culture of the red algal genus Eucheuma in the Philippines.
1974 Aquaculture, 3:355-68

Pham Hoang Ho, Contribution à l'étude du peuplement du littoral rocheux du Sud-Vietnam.
1961 Thèse, Paris. (Also available in Vietnamese, 1969)

Soerjodinote, Is the cultivation of seaweed (Eucheuma spinosum and Eucheuma edule) in Indo-
1969 nesia technically possible and economically justified? Occas.Pap.IPFC,(69/6):4 p.

Subba Rao, G.N., Use of seaweeds directly as human food. Reg.Stud.IPFC, (2):32 p.
1965

Sulit, J.T., O.B. Navarro and R.C. San Juan, Chemical studies and utilization of some
1953 Philippine seaweeds. Proc.IPFC, 4(2):165-70

Sulit, J.I., L.G. Salcedo and P.C. Panganiban, Studies on the bleaching and utilization
1955 of Gulamandagat (Gracilaria confervoides). Tech.Pap.IPFC, (29):5 p.

Tsuda, R.T., Preliminary bibliography on the marine benthic algae in the Central Pacific,
1966 Polynesia and Micronesia. Tech.Rep.Hawaii Inst.Mar.Biol., (10):13 p.

Trono, G.C. Jr., The benthic algae of the Caroline Islands, 1. Introduction, Chlorophyta
1968 and Cyanophyta. Micronesia, 4(2):137-206

__________, The benthic algae of the Caroline Islands, 2. Phaeophyta and Rhodophyta.
1969 Micronesia, 5(1):25-119

Velasquez, G.T., Seaweed resources of the Philippines. Proc.Int.Seaweed Symp., 1:100-1
1953

__________ Studies and utilization of the Philippine marine algae. Proc.Int.Seaweed
1972 Symp., 7:62-5

Velasquez, G.T. et al., Algal communities of exposed and protected marine waters of
1971 Batangas and Bataan. Philipp.J.Sci., 100(1):1-40

Villaluz, D.K., Algae culture in brackish-water ponds of the Philippines. Contr.Pap.
1949 IPFC, (4)

Zaneveld, J.S., The economic importance of seaweeds and the possibility of their
1949 exploitation in the Malayan Archipelago. Chron.Nat., 105(1) (in Dutch)

__________, The economic marine algae of Malaysia and their applications. Tech.Pap.
1952 IPFC, (35):1-26

__________, The economic marine algae of the tropical regions of South and East Asia
1955 and their utilization. Spec.Publ.IPFC, (3):55 p.

__________, The utilization of marine algae in tropical South and East Asia. Econ.Bot.,
1959 13(2):89-131

FISHING AREA 77 : EASTERN CENTRAL PACIFIC

Two main resources are being utilised: the giant kelp beds of California-North Mexico and certain agaroid red algae of the Baja California peninsula.

1. U.S.A.

1.1 Alginophyte

Macrocystis pyrifera is distributed from the Monterey peninsula in central California to the middle of the Baja California west coast. North of Monterey this giant kelp is replaced by *M. integrifolia* and *Nereocystis leutkeana*, the latter intruding into the northernmost part of the *M. pyrifera* area (Druehl, 1970).

In 1968 the combined harvest from California and Mexico was 148 305 metric tons of fresh kelp, according to Silverthorne and Sorensen (1971) with reference to a communication from Philip R. Park Company. This total is consistent with other known data, while the official U.S. figure as forwarded to the FAO Yearbook of Fishery Statistics is confusing: 0.1 thousand metric tons for the Northeast Pacific fishing area, no figures for Eastern Central Pacific. Assuming that the official figure for Mexico - 28 200 tons - is founded on the same estimate as the total, the California part would be 120 100 t for 1968. Of the total California and Mexico harvest 124 700 t were used by Kelco Company of San Diego for the manufacture of algin, the remaining 23 600 t were processed to seaweed meal by two other manufacturers. Kelco also imported about 1 460 t of dried seaweed to produce an estimated 3 880 t of algin, or 30 percent of the world production.

Among the natural seaweed resources of the world the giant kelp of California is the most comprehensively investigated. The present knowledge of the biology of giant kelp beds is summarized in a 600-page volume (North, 1971). An earlier summing up concentrated on the impact of man on the kelp environment and the kelp itself (North and Hubbs, 1968). Continuous reports are given from 1957 to 1963 by the Kelp Investigation Program (North, Ed., 1957-63), since 1963 reorganised in the Kelp Habitat Improvement Project (North, Ed., 1965-74).

Of more than historical interest are early investigations (Cameron, 1912, 1915; Setchell, 1912; Turrentine, 1912; Wohnus, 1942; Tseng, 1947; Scofield, 1959). This resource is also accounted for more or less in detail in reviews such as by Kirby (1953), Boney (1965) and Chapman (1970). As this abundant literature will fill any need for thorough information, only the main problems and the main investigations will be mentioned here.

The 1911-13 survey of kelp quantities on the U.S. and Mexico Pacific coasts (already quoted for the Northeast Pacific area) gave as annually harvestable quantities:

	Nereocystis	Mixed	Macrocystis
Cape Flattery-Point Conception	3 349 540	279 180	748 680
Point Conception-San Diego			18 195 000
San Diego-Cedros Island			16 980 000

The first of these coastlines corresponds to the northern two-thirds of California, but also includes Oregon and most of Washington which are here assigned to the Northeast Pacific. A very rough breakdown should set the Californian part at 2.5 million t, giving a total for California of 20.7 million t and Eastern Central Pacific of 36.7 million t. These figures do not correspond to standing crop but to the result of two annual harvests at 1 m below the sea surface. Tseng (1947), starting from the actually harvested quantities, such as 0.4 million t in 1917 between Point Conception and San Diego, and judging that 1 million t per annum could be harvested in this area, concludes that these

early estimates should be reduced to 5 percent of the data given. On the same basis, the productivity of the total U.S. Pacific kelp beds may be placed at about 3 million t per annum. For 1940–45 the Californian mean annual harvest was 56 000 t, or one-seventh of those obtained during 1917 and 1918.

Old data give an idea of the potential productivity of the area, but must not be used for an estimate of the quantities now available. In the 1940s and 1950s there was extensive depletion of the kelp beds. The direct cause of the disappearance was usually identified as overgrazing by dense populations of sea urchins (California Water Quality Control Board, 1964). The indirect cause is in many cases pollution, which seems to favour the development of sea urchins. In polluted areas these may be found in quantities of 100 individuals per m^2. In other cases overpopulation of sea urchins and vanishing kelp beds have been the biological consequence of the extermination of sea otter, an urchin predator, which was hunted for its valuable fur.

The California kelp programmes include various studies of the depletion of beds and sea urchin biology (e.g., Leighton, 1966; Leighton and Jones, 1968) and in particular studies and experiments aiming at the restoration of beds. This can be achieved through sea urchin combating. The most successful technique is quicklime operations, accounted for in all the annual reports by North (Ed., 1965–74) mentioned above. The chemical is dispersed in large lumps into the wake of a moving vessel. If a lump settles on an urchin, tissue is destroyed and the animal dies. Quicklime rapidly combines with water to form harmless calcium carbonate, so no lasting poison is introduced into the environment by the method. Total elimination of the urchins can be accomplished in a small area if divers crush the urchins with hammers (North, Ed., 1967, 1971).

Where Macrocystis has disappeared totally, it can be restored by cultivation and transplantation (North, 1964; North (Ed.) in Annual reports cited: 1967, 1970, 1971; North and Mitchell, 1968; North and Neushul, 1968; North, Mitchell and Jones, 1969; Parker, 1971). When a suitable kelp bottom has been freed from sea urchins, mature kelp plants are moved to it or embryonic sporophytes, raised in artificial cultures, are "seeded". If not, other seaweed species from the local flora will take over the liberated surfaces.

The kelp beds are rich in fish and are much esteemed by sport fishermen. No adverse effect of harvesting on fishing was observed (Quast, 1968). Actually kelp-bass fishing was found to be better in harvested beds than in uncut beds (Davies, 1968).

Drifting kelp is also associated with fish, this however recruited from pelagic stocks. In the shelter of the kelp they are pursued less often, for shorter periods, and captured less frequently by a predator. Near drifting plants there is a fishing for yellowtail, albacore and occasionally dolphin fish (Mitchell and Hunter, 1970).

The impact of pollution on the kelp ecosystem is considerable (California Water Quality Control Board, 1964; Pierce _et al_., 1970)

In the extensive literature from the kelp projects there is no information on tonnages; in studies of correlation to regrowth and other factors the quantities harvested are merely given as relative figures with year of maximum harvest arbitrarily taken as a base. It is revealed only that approximately one-third of the beds provide two-thirds of the state-wide harvest. It seems reasonable to conclude that the potential is considerably higher than the harvests actually drawn.

Aleem (1956, 1973), diving at La Jolla through the community of which _Macrocystis_ is the dominating component, assessed quantities by the quadrant method. In shallow water the sea grass _Phyllospadix scouleri_ covered 80–100 percent of the rock surface to an average of 3.6 kg/m^2. The standing crop of the _Macrocystis_ plants was estimated at 6–10 kg/m^2 with an average annual yield of 10–15 t/ha (only some 15 percent of the biomass). Deeper than the sea grass community, two laminarian kelps, _Pterygophora_ and

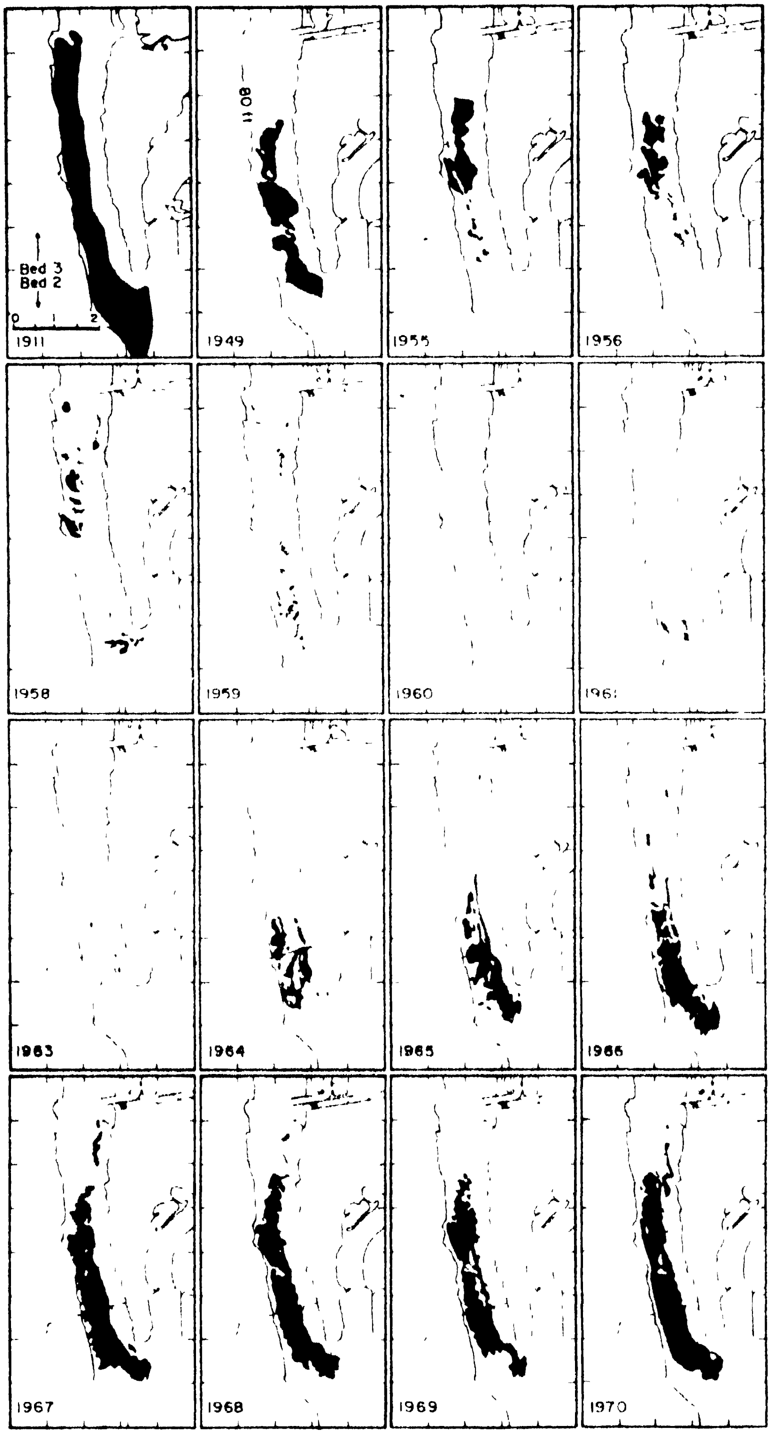


Figure 10. Historical charts of the Point Loma kelp bed (shown as black). 1963 to 1966 from oblique photos, courtesy Kelco Company. Years 1963 to 1971 represent fall conditions. Scale: nautical miles. (From North, 1971)

Eisenia, form, together with Laminaria farlowii, a "forest" under the large Macrocystis plants; this sub-forest is best developed between 10 and 20 m, its biomass was estimated at 3.15 kg/m^2. A bottom stratum of coralline algae and associated animals forms a cover under the larger kelps. The weight of the turf algae, which prefer shadow, averaged 1.6 kg/m^2 in the bed as a whole. An average figure for the standing crop of the organisms inhabiting the rocky bottom of the kelp beds, including Macrocystis itself, would approach 9.4 kg/m^2 of sea bottom (Aleem, op.cit.)

In Paradise Cove, McFarland and Prescott (1959) found in a similar investigation 4-5.3 kg/m^3 of giant kelp. From 25 to 43 percent of the wet kelp biomass was found in the canopy. The undergrowth, even when containing dense stands of young Macrocystis, was very poor compared to that assessed by Aleem and never exceeded 0.5 kg/m^2. Beneath dense kelp canopies in the centre of the bed it gave an average wet standing crop of 0.004 kg/m^2. It was calculated that undergrowth constitutes about 2 percent of the total plant biomass within the kelp bed.

1.2 Agarophyte

The high cost of labour in the United States discourages any extensive harvesting of seaweed for agar. Several years ago the American Agar and Chemical Company attempted unsuccessfully to mechanize the harvesting of the agar weed. Until some means of mechanical harvesting can be developed, it is unlikely that significant amounts of red algae will be gathered off the U.S. coast (Durrant, 1967).

Gelidium cartilagineum is the most important agaroid. An indication of the quantities available can be obtained from data on harvested amounts during the last world war. In 1944, 240 t wet weight, or about 80 t dry weight, was collected. The agarweed resource of southern California waters is undoubtedly many times the 240 t actually gathered since harvesting was then limited to only a few readily accessible shores very close to Los Angeles. A small fraction was taken close to San Diego. Wartime restrictions prevented operations in numerous places. Even where Gelidium was gathered, more was probably left than harvested. There are reasons to believe that southern California, if thoroughly but sensibly exploited, could yield more than 1 500 t of fresh agarweed per annum (Tseng, 1947).

Gelidium grows abundantly from Point Conception in the north to Magdalena Bay in Baja California. Beginning in 1920, commercial agar production in the United States has undergone several booms and crises. Today only one firm, American Agar and Chemical Company of San Diego, remains in operation. This firm manufactures high grade bacteriological agar using Gelidium from Mexico and many other parts of the world (Silverthorne and Sorensen, 1971).

2. Mexico

In continuation of its distribution in California, Macrocystis pyrifera grows in extensive but interrupted sectors to Punta San Hipólito and very rarely to Isla Magdalena. The wet weight production has been increasing: 10 000 t in 1956, 14 000 t in 1960 and 37 000 t in 1974. This is still very modest compared to the early estimates of harvestable quantities amounting to 8 500 000 t (Cameron, 1915) or 425 000 t (Tseng, 1947). With the aid of aerial photographs Guzmán del Próo et al. (1971) map the beds and also give a breakdown of harvests on years and areas. In spring and summer the harvest is 14-35 kg/m^2, in winter 5-10 kg/m^2. The exploitable biomass is estimated at 65 000 t and maximum harvestable at 147 500 t (Guzmán del Próo, in press). Other large brown algae are Egregia laevigata and Pelagophycus porra, known as "bule", which live associated with the Macrocystis beds. The volumes are far from those of Macrocystis, however they appear as a small fraction mixed with this species during harvesting. Eisenia arborea has rather much the same distribution, grows in volumes of considerable magnitude, is cast ashore in enormous quantities after storms, but is not exploited. The quantities are no doubt commercial.

Gelidium cartilagineum is the dominating agarophyte. The harvests are rapidly increasing: 59 t in 1955, 264 t in 1960, 800 t in 1965. These values are dry weight

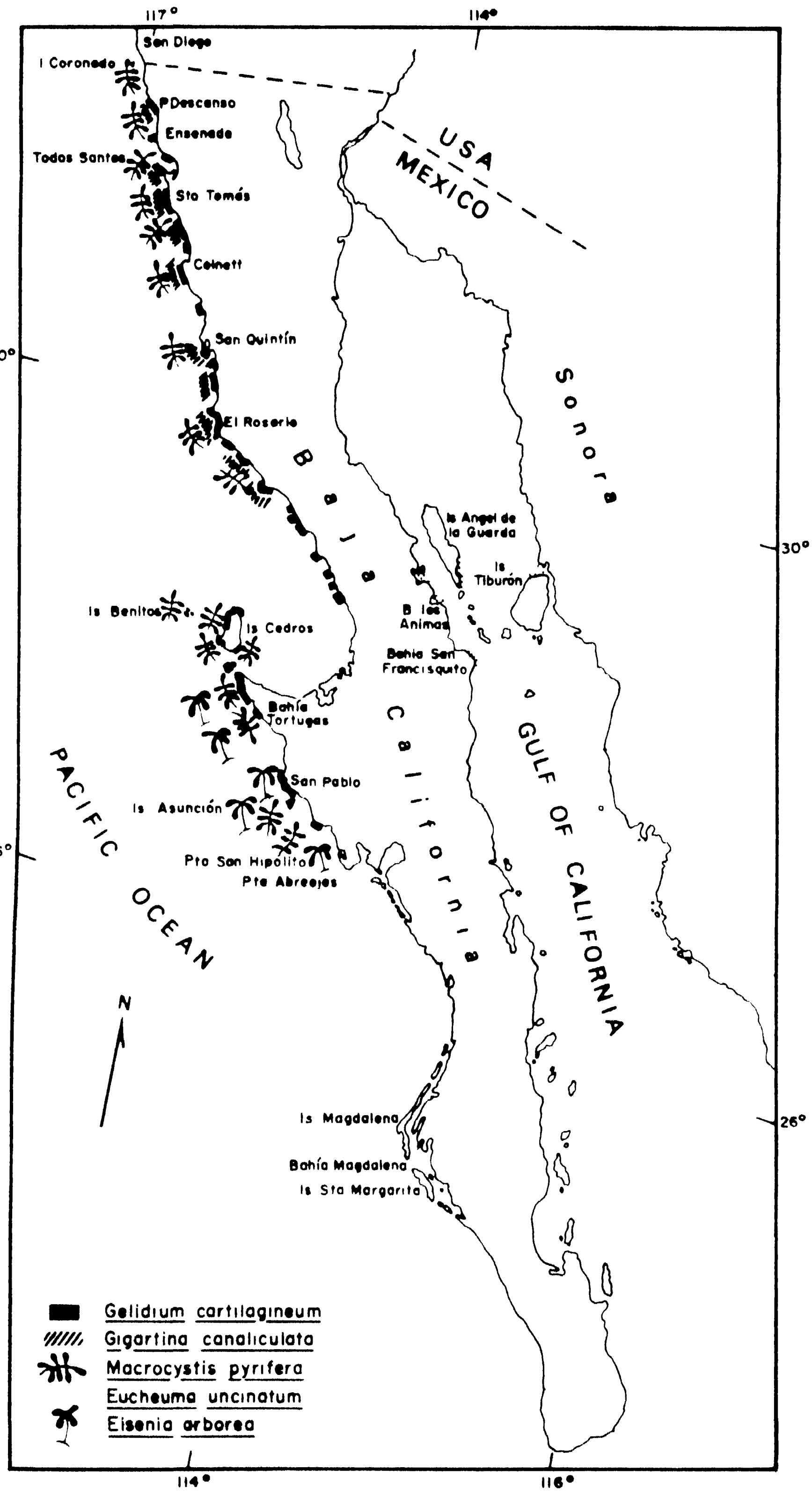


Figure 11. Mexican marine algae in commercial quantities. (After Guzmán del Próo, 1969)

values (Guzmán del Próo, 1969). The harvests of red algae increased further to a maximum of 2 451 dry t in 1974. The resources are found from the low-water line to 15 and 17 m, most of them exploited between 4 and 8 m. Most of the harvest is collected by skin-divers. The Agar-Mex factory in Ensenada consumes a great part of the present harvest, but some quantities are exported to plants in San Diego. One problem is to get enough fresh water in Baja California, another is that 70 percent of the Gelidium plants are covered by bryozoan colonies (Guzmán del Próo et al., 1974).

Gigartina canaliculata has been exploited only for a few years, but the harvests are rapidly increasing; in 1974, 638 t dry weight. It is collected by hand at low water (Guzmán del Próo et al., 1974).

Eucheuma uncinatum is not yet utilized but an assessment of quantities arrived at an estimate of 1 650 t wet weight corresponding to 165 t dry weight. Further potential resources are Porphyra perforata, Agardhiella tenera, Eucheuma isiforme, Gracilaria verrucosa and Hypnea musciformis (Guzmán del Próo, 1969). A review in Spanish of the preparation of agar was given by Osorio Tafall (1946).

3. Guatemala

There are no records of species or quantities.

4. El Salvador

A bilingual flora of intertidal algae was drawn up by Dawson (1961).

5. Nicaragua

A number of species are identified by Dawson (1962).

6. Costa Rica

The algae have been described by Taylor (1945) and Dawson (1957, 1962).

7. Panama
8. Colombia
9. Ecuador

Several localities in these countries were investigated during the Allan Hancock Pacific Expedition in 1934 (Taylor, 1945). Particular interest was devoted to the Archipelago de Colón (Galapagos Islands). Additional information on the Galapagos Islands has been given by Dawson (1963).

10. Clipperton Island

The algal vegetation of this solitary atoll southwest of Mexico was recorded by Dawson (1959).

11. Samoa

As in Hawaii, seaweeds are collectively known as "limu" and a great number of species are eaten. A list of 25 vernacular terms related to edible seaweeds is given by Garlovsky (1971), together with 20 species identified by Drumgole. Besides the ones eaten as food, the red alga Chronidris is mentioned as very useful for eliminating Ascaris worms from the intestine of man and pigs.

References to the marine benthic algae of the island groups of Fiji and Niuafooru (in Western Central Pacific, Area 71), and Samoa, Tonga, Cook, Society, Tubai, Tuamotu and Easter Islands are found in Tsuda, 1966.

12. Hawaii

Fish and taro paste were the staple food of the native Hawaiians. During famine and war their only food came from the sea and there are over 70 distinct species of algae used for food. In the beginning of the century 40 of these were in general use. Reed (1907) estimates the quantities sold each year in the Honolulu fish market at 2 200 kg of "limu", algae. Of this total about 900 kg is "limu kohu", Asparagopsis sanfordiana, about the same amount of "limu eleele" and "limu oolu" or Enteromorpha spp. and Chondria tenuissima respectively; the rest is made up of a high number of comparatively scarce species of Laurencia, Gracilaria, Dictyota, Haliseris, Hypnea and Naias. At the time every Hawaiian who bought a fish or a lobster also bought his plate of "limu".

Setchell (1905) gives a dictionary of more than 100 Hawaiian words for various kinds of limu, discussing their identity and use. Generally they are divided into two classes, one which will keep in condition for eating for as long as a year, one called "one day limu". All the fishermen agree that limu are eaten raw, occasionally some kind is boiled with fish or shrimps, so as to dissolve and form a jelly when cooled, or is used to wrap around a pig or a dog when cooked underground, when those portions smeared with fat or drippings are much esteemed.

REFERENCES

Aleem, A.A., 1956 A quantitative study of the benthic communities inhabiting the kelp beds off the California coast, with a self-contained diving apparatus. Proc.Int.Seaweed Symp., 2:149–52

______, 1973 Ecology of a kelp bed in southern California. Bot.Mar., 16(2):83–95

Boney, A.D., 1965 Aspects of the biology of the seaweeds of economic importance. Adv.Mar.Biol., 3:105–253

California Water Quality Control Board, 1964 An investigation of the effects of discharged wastes on kelp. Publ.Calif.Water Qual.Control Board, (26):124 p.

Cameron, F.K., 1912 A preliminary report on the fertiliser resources of the United States. Washington, D.C., U.S. Senate, Doc. 62nd Congress, 2nd Session (190):290 p.

______, 1915 Potash from kelp. Rep.U.S.Dep.Agric., (100):122 p.

Chapman, V.J., 1970 Seaweeds and their uses. London, Methuen and Co., 304 p.

Davies, D.H., 1968 Statistical analysis of the relation between kelp harvesting and sport-fishing in the California kelp beds. In Utilisation of kelp-bed resources in southern California, compiled and edited by W.J. North and C.L. Hubbs. Fish.Bull., Calif., (139):151–212

Dawson, E.Y., 1957 Marine algae of the Pacific Costa Rican gulfs. Contrib.Sci.Los Ang.Cty. Mus., (15):28 p.

______, 1959 Some algae from Clipperton Island and the Danger Islands. Pac.Nat., 1(7):2–8

______, 1961 Plantas marinas de la zona de las mareas de El Salvador (Intertidal marine plants of El Salvador). Pac.Nat., 2(8):388–461

Dawson, E.Y., Additions to the marine flora of Costa Rica and Nicaragua. Pac.Nat., 3(13):
1962 375-95

__________, New records of marine algae from the Galapagos Islands. Pac.Nat., 4(1):3-23
1963

Druehl, L.D., The pattern of Laminariales distribution in the Northeast Pacific.
1970 Phycologia, 9(3/4):237-47

Durrant, N.W., The west coast's seaweed industry. Commer.Fish.Rev., 29(5):65-8
1967

Garlovsky, D., List of algae found in Western Samoa. In South Pacific islands - marine
1971 turtle resources; a report prepared for the Fisheries Development Agency Project, by H.F. Hirth. Rome, FAO, FI:SF/SOP/REG/102/2:31-3

Guzmán del Próo, S.A., Los recursos vegetales marinos de Baja California, México. Proc.
1969 Int.Seaweed Symp., 6:685-90

Guzmán del Próo, S.A., Sargazo flotante. In Diagnóstico de la situación actual de las Pesquerías de México, pp. 206-26 (in press)

Guzmán del Próo, S.A., S. de la Campa de Guzmán and J.L. Granados Gallegos, El sargazo
1971 gigante (Macrocystis pryifera) y su explotación en Baja California. Rev.Soc. Mex.Hist.Nat., 32:15-49

Guzmán del Próo, S.A., S. de la Campa de Guzmán and J. Pineda Barrera, La cosecha de algas
1974 comerciales en Baja California. Ser.Divulg.Inst.Nac.Pesca, Méx., (6):15 p.

Kirby, R.H., Seaweeds in commerce. London, Her Majesty's Stationery Office, 157 p.
1953

Leighton, D.L., Ecological investigations of sea urchin populations along the Palos
1966 Verdes peninsula. In Annual Report, 1 April 1965-31 March 1966. Kelp habitat improvement project, edited by W.J. North. San Diego, California, California Institute of Technology, W.M. Keck Laboratory of Environmental Health Engineering, pp. 72-82

Leighton, D.L. and L.G. Jones, Ecological investigations of sea urchin populations along
1968 the Palos Verdes peninsula. Annu.Rep.Kelp Habitat Improv.Proj., Calif.Inst. Technol., 1967/68:39-62

McFarland, W.N. and J. Prescott, Standing crop chlorophyll content and in situ metabolism
1959 of a giant kelp community in southern California. Publ.Inst.Mar.Sci.Univ.Tex., (6):109-32

Mitchell, C.T. and J.R. Hunter, Fishes associated with drifitng kelp, Macrocystis pyrifera,
1970 off the coast of southern California and northern Baja California. Calif.Fish Game, 56(4):288-97

North, W.J., Experimental transplantation of the giant kelp, Macrocystis pyrifera. Proc.
1964 Int.Seaweed Symp., 4:248-55

__________, (Ed.) Quarterly progress report. Kelp investigation program, Univ. Calif.,
1957-63 (1957)-(1963)

__________, (Ed.) Annual report. Kelp habitat improvement project. Calif.Inst.Technol.,
1965-74 (1965)-(1974)

North, W.J., (Ed.) Biology of the giant kelp beds (Macrocystis) in California. Nova
1971 Hedwigia 32, Suppl:600 p.

North, W.J. and C.L. Hubbs, (eds), Utilization of kelp-bed resources in southern California.
1968 Fish Bull.Calif., (139):264 p.

North, W.J. and C.T. Mitchell, Techniques for establishing new kelp beds. Annu.Rep.Kelp
1968 Habitat Improv.Proj.,Calif.Inst.Technol., 1967–68:99–102

North, W.J. and M. Neushul, A note on the possibilities of large scale cultivation of
1968 Macrocystis. Fish Bull.Calif., (139):17–24

North, W.J., C.T. Mitchell and L.G. Jones, Mass cultures of Macrocystis. Annu.Rep.Kelp
1969 Habitat Improv.Proj.,Calif.Inst.Technol., 1967–68:48–69

Osorio Tafall, B.F., La obtención del agar en Baja California. Ciencia Mex., 1946:43–56
[1946]

Parker, B.C., Studies of translocation in Macrocystis. In Biology of the giant kelp
1971 (Macrocystis) in California, edited by W.J. North. Nova Hedwigia, 32 Suppl.

Pierce, J.S., et al., Marine waste disposal and sea urchin ecology. Washington, D.C., U.S.
1970 Dept. of the Interior, Federal Water Quality Administration

Quast, J.C., Observations on the food and biology of the kelp bass, Paralabrax clathratus
1968 with notes on its sport-fishery at San Diego, California. Fish Bull.Calif., (139):81–108

Reed, M., The economic seaweeds of Hawaii and their food value. Annu.Rep.Hawaii Agric.
1907 Exp.Stn., pp.61–88

Scofield, W.L., History of kelp harvesting in California. Calif.Fish Game, 45(3):135–57
1959

Setchell, W.A., Limu. Univ.Calif.Publ.Bot., 2(3):91–113
1905

__________, The kelps of the United States and Alaska. In A preliminary report on the
1912 fertilizer resources of the United States. Washington, D.C., U.S. Senate Doc. 62nd Congr., 2nd Sess.(190), Appendix K, pp.130–78

Silverthorne, W. and P.E. Sorensen, Marine algae as an economic resource. Prepr.MTS (Mar.
1971 Technol.Soc.)Annu.Conf., 7:523–33

Taylor, W.R., Pacific marine algae of the Allan Hancock expedition to the Galapagos Islands.
1945 Rep.Allan Hancock Pac.Exped., 12:528 p.

Tseng, C.K., Seaweed resources of North America and their utilization. Econ.Bot., 1(1):
1947 69–97

Tsuda, R.T., Preliminary bibliography on the marine benthic algae in the Central Pacific,
1966 Polynesia and Micronesia. Tech.Rep.Hawaii Inst.Mar.Biol., (10):13 p.

Turrentine, J.W., The technology of the seaweed industry. In A preliminary report on the
1912 fertilizer resources of the United States. Washington, D.C., U.S. Senate Doc. 62nd Congr., 2nd Sess.(190), edited by F.K. Cameron. Appendix Q, pp.232–62

Wohnus, J.F., The kelp resources of southern California. Calif.Fish Game, 28(4):199–205
1942

FISHING AREA 81 : SOUTHWEST PACIFIC

1. Australia

On the Australian continent Gracilaria verrucosa is the dominant resource of the east coast. In the Botany Bay area south of Sydney, trawling with a crew of three men brought 270–360 kg/h (Chapman, 1970). Along the 1 370 km coastline of New South Wales there has been estimated to be enough seaweeds to supply 100 t of agar annually, according to Chapman. He gives the conversion 21 t of wet Gracilaria to 1 t of agar. More than 2 000 t of Gracilaria, however, seems excessive. Attempts have also been made to cultivate Gracilaria.

Eucheuma grows on coral reefs off the coast of Queensland. Only drift weed would be possible to harvest.

2. New Zealand

Pterocladia occurs in two species which give the raw material for a small agar-extracting factory. Owing to the shortage during the war, these weeds were investigated and found to yield a gel of a strength superior to that of Japanese Kobe (Forsdike, 1950). Moore (1944, 1946) discusses aspects of the early stages of agar production in New Zealand, quoting as an example of catch per unit effort, that a good collector can gather about 20–35 kg dry weight in one tide in a good place. Kirby (1953) reviews processing properties and economics in detail. Schwartz (1953) gives an account of seaweed utilization in New Zealand with emphasis on manufacturing problems such as the discolouration of agar by metal ions and the conditions under which metal ion contamination occurs.

Agarophytes, principally P. lucida, grow mainly on North Island shores and are collected by hand from rocks about low tide or are gathered from drift after storms. The weed is sun-dried and packed for dispatch to the factory in the South Island. Watkinson and Smith (1972) list figures of dry weed gathered for processing in the years 1962–71, giving an average of 126 t/year. For a number of years agar could be manufactured in New Zealand only under licence; although this restriction no longer applies the original firm is still the only processor.

Gelidium spp. in New Zealand are too small and the Gracilaria spp. of too low quality to have any potential value at the present time.

Macrocystis pyrifera grows in Foveaux Strait and Cook Strait in beds which have been estimated to yield about 5 200 t of dried seaweed per annum on the basis of 80 percent harvestable, one and a half harvests per year (Rapson, Moore and Elliot, 1943). No results have been published of recent aerial surveys.

Durvillea, bull kelp, is a very massive fucoid growing on exposed rocky coasts in two species, D. antarctica having a wider distribution than the endemic D. willana. Where the two occur together, D. antarctica grows just inshore of D. willana and is more easily harvested. A single plant of either species can reach a length of 4–5 m and a wet weight of 50 kg (15–20 kg dry weight). Methods of harvesting, drying and packing are being investigated, but the economic prospects are still uncertain. Harvesting for commercial use began in 1971 and currently exploitation is restricted to the southeast section of the South Island. After drying the bull kelp is pulverized for export. No production figures are available (Watkinson and Smith, 1972). Formerly, the Maoris made air-tight bags from Durvillea in a truly masterly fashion, described by Schwartz (1953), who regrets that this primitive art is dying.

Large amounts of beached seaweeds exceeding amounts occurring in California are found along the coast of the South Island. Farmers salvage considerable amounts for soil conditioning purposes. The figure given by ZoBell (1971), 20 000 t/year in the Canterbury Plains alone, is regarded as exaggerated by New Zealand phycologists.

Other brown algae reaching a length of more than 1 m, such as species of Cystophora, Carpophyllum, Lessonia and Ecklonia, might be used for fertiliser or alginate production, but present use is restricted to gardening. Liquid fertilisers are extensively advertised in New Zealand but apparently the partly processed material is all imported from other countries (M.J. Parsons, personal communication).

Gigartina is represented by 20 species offering a range of carrageenans of different properties and qualities. Small amounts are collected for domestic use and perhaps about 1 t wet weight/year is used to manufacture custard-like commodities and by one or two breweries for fining beer.

Porphyra is traditionally eaten by the Maoris but only in small quantities and it is not on sale. They have also used Gigartina, Macrocystis and green seaweeds as food.

REFERENCES

Chapman, V.J., 1970 Seaweeds and their uses. London, Methuen and Co., 304 p.

Forsdike, J.L., 1950 A comparative study of agars from various geographical sources. Chemist and Druggist, October 14:796-806

Kirby, R.H., 1953 Seaweeds in commerce. London, HMSO, 157 p.

Moore, L.B., 1944 New Zealand seaweed for agar manufacture. N.Z.J.Sci.Technol., 25(5)

__________, 1946 New Zealand seaweed for agar manufacture. N.Z.J.Sci.Technol., Sect.B, 25: 183-209

Rapson, A.M., L.B. Moore and I.L. Elliot, 1943 Seaweed as a source of potash in New Zealand. N.Z.J.Sci.Technol., Sect.B, 23:149-70

Schwartz, E.F., 1953 The utilization of seaweed in New Zealand. Proc.Pac.Sci.Congr., 7:70-8

Watkinson, J.G. and R. Smith, 1972 New Zealand fisheries. Wellington, 91 p.

ZoBell, C.E., 1971 Drift seaweeds of San Diego County beaches. In The biology of giant kelp beds (Macrocystis) in California, edited by Wheeler J. North. Nova Hedwigia (Beih.), 32:269-314

FISHING AREA 87 : SOUTHEAST PACIFIC

At present *Gracilaria* spp. are the most important seaweeds from an economical standpoint. Kim (1970) approximates the quantities in the 11 principal *Gracilaria* beds, totalling 7.7 km^2, to 130 000 t wet weight (22 000 t dry weight). Of these, 24 000–30 000 t are exploited annually (4 000–5 000 t dry weight). In 1968, 1 600 t dry weight were exported, or four times more than the total export of *Iridea*, *Gelidium* and *Gigartina* (295 t, 61 t, and 18 t respectively).

There are two main areas of harvesting of *Gracilaria*: in the vicinity of Concepción (37°S) and of Canal de Chacao (42°S). Methods for collecting and drying and the activities of a fishing cooperative are described by Cable (1974). Two factories in Chile are working with seaweeds as raw products; one for alginates, with a production capacity of 50–60 t, and the other for agar-agar, with a capacity of 300 t a year.

The useful species were treated by Etcheverry (1953, 1958, 1960) and Llaña (1948). Kim (1968), in a plan for further investigations of industrially useful marine algae, recommends 21 areas in 11 provinces from Tarapacá (20°S) to Chiloé (42°S). An FAO/UNDP fisheries project (unpublished) surveyed northern Chile and found that, apart from the Coquimbo area, the seaweed resources were insufficient for industrial exploitation. A transplant of *Gracilaria* was made into what appeared a suitable area in the north, but although it grew, the rate of growth was very inferior to that in the south or in central Chile and the venture was not considered a success (J. Molteno, personal communication).

It is likely that the total bulk of algal mass is larger in the southern third of Chile. Here kelp species are dominating, such as *Macrocystis*, which may grow down to depths of 20 m and can then be harvested at some distance from the shoreline. In Chile, however, this kelp does not occur in a continuous fringe along the coast but in separate patches between which very little or nothing is found (Kim, 1968). The Straits of Magellan are assumed to hold one of the largest fairly untapped seaweed resources in the world. Its quantity and possible utilization is being investigated, and this might be expected to result in an alginate factory. There are, however, technical disadvantages - lack of communications, distance from markets and very poor weather conditions. On the other hand, collection and processing of *Macrocystis* would contribute essentially to the development of the region.

The most important seaweed species are brown algae: *Macrocystis pyrifera* and *Durvillea antarctica*, found in south and central Chile, and *Lessonia nigrescens*, also found in north Chile. Other kelp species are *Lessonia flavicans* and *Durvillea harveyi*, in south Chile. Red algae: in addition to *Gracilaria*, *Iridea*, *Gelidium* and *Gigartina* already mentioned, there are *Chondrus*, *Ahnfeltia*, *Gymnogongrus* and *Agardhiella* spp. of industrial interest.

The laver species *Porphyra columbina* and the sea lettuce *Ulva lactuca* are marketed for human consumption. The holdfast and stipe of *Durvillea antarctica* are cooked or eaten raw in salads; they are also used by pharmaceutical producers in children's food on account of their high iodine content (Etcheverry, 1953).

2. Peru

Hilde Juhl-Noodt (1958) has made assessments of the "great and famous resources of marine algae" in Peru, as stated in her species list.

Gigartina chavinii and other *Gigartina* species are frequently found in the littoral as well as in the sublittoral. They are eaten; the vernacular name for dried algae is

"uyo". Ahnfeltia durvillaei is characteristic for the supralittoral. Dense tufts appear almost everywhere on the rocky coast at the splash levels and are missing only in a few sheltered places. In the far north they seem to avoid the points with the strongest breakers. They are also found in the entire littoral, where they are differently developed; darker, more slender and slack. Gelidium, Chondrus, Rhodymenia and Dendrymenia species are also recorded.

Macrocystis pyrifera is found in many places in the sublittoral (from 3–12 m) in thick stands together with Lessonia nigrescens. Macrocystis integrifolia, littoral and sublittoral to 20 m, is found as far to the north as 9°S, M. pyrifera only to 12°S. The genus is said to have its distribution limit in waters at the 20°C isotherm for the warmest month. Lessonia nigrescens may cover vast sublittoral areas in pure stands and may also occur in thick stands together with Macrocystis. The possible utilization of the undoubtedly rich seaweed resources of Peru was discussed by Juhl-Noodt (1959) and Acleto Osorio (1970, 1971).

REFERENCES

Acleto Osorio, C., 1970 Las algas marinas: riqueza inexplotada. Pesca, 20(5):8–12

______, 1971 Algas marinas del Perú de importancia económica. Univ.Mayor de San Marcos, Perú, Museo Hist.Nat. "Janvier Prado", Ser.Divulg., (5):85 p.

Cable, W.D., 1974 A description of the activities of the Maullin (Chile) Fishing Cooperative in the extraction of the marine alga Gracilaria sp. January–March 1967. Bot. Mar., 17(1):60–2

Etcheverry, D.H., 1953 Seaweed resources of Chile. Proc.Int.Seaweed Symp., 1:108

______, 1958 Algas marinas chilenas productoras de ficocoloides. Rev.Biol.Mar., 8:153–74

______, 1960 Algas marinas de las islas oceánicas chilenas. Rev.Biol.Mar., 10(1–3): 83–132

Juhl-Noodt, H., 1958 Beiträge zur Kenntnis der peruanischen Meeresalgen. 1. Kieler Meeresforsch. 14(2):167–74

______, 1959 Las algas marinas de la costa peruana y las posibilidades de su utilización. Bol.Cia.Adm.Guano, 35(6):16–30

Kim, D.H., 1968 Algunas consideraciones sobre la utilización industrial de algas marinas en Chile. Universidad de Concepción, Laboratorio de Algas, Instituto Central de Biología (mimeo)

______, 1970 Economically important seaweeds in Chile. 1. Gracilaria. Bot.Mar., 8: 140–62

Llaña, A.H., 1948 Algas industriales de Chile. Rev.Biol.Mar., 1:124–31

FISHING AREA 48 : ANTARCTIC ATLANTIC
58 : ANTARCTIC INDIAN OCEAN
88 : ANTARCTIC PACIFIC

Only part of Graham's Land between 55° and 65°W reaches north of 65°S. It is here that most phycological work has been done.

The Macrocystis fringe as well as Lessonia and Durvillea, all characteristic of subantarctic waters as in Fuegia or Falkland, is absent in genuine Antarctic waters as around the South Shetlands or the Antarctic Peninsula (Skottsberg, 1964).

The vertical distribution of the marine flora has been investigated (Skottsberg, 1941, 1964; Neushul, 1965; Delépine et al., 1966; Zaneveld, 1966; McCain and Stout, 1969). The last four papers mentioned are based on observations made during SCUBA divings. Ice-free littoral shores are few and more or less devoid of algae; the sublittoral vegetation, however, is rather rich down to 42 m (the deepest point reached by diving scientists) and dominated by the kelp Phyllogigas grandifolias. Certain species of Picconiella and Plocamium brought up on fish lines from depths down to 100 m indicate that they might have been growing attached as deep as that.

In the sublittoral region, there is abundant algal growth, also under ice covers 2-3 m thick (Zaneveld, 1966). The distribution of important species has been mapped (Balech et al., 1969).

No quantitative assessment has been made.

The sector most frequently investigated is the one which lies closest to another continent, South America. It must be borne in mind, however, that there are difficulties for the utilization of the extremely rich resources of Chile and Argentina, arising from the fact that already these resources are regarded as being situated too far from available labour, communications and consumers to be economically attractive and in an area where climatic conditions limit desired activities to a rather short period each year. These difficulties must be much more serious for any utilization of the comparatively much poorer resources of the Antarctic continent. They do not provide a possible resource for utilization.

REFERENCES

Balech, E. et al., 1969 Primary productivity and benthic marine algae of the Antarctic and Subantarctic. Antarct.Map Folio Ser., (10):15 plates

Delépine, R., I.M. Lamb and M.H. Zimmermann, 1966 Preliminary report on the marine vegetation of the Antarctic Peninsula. Proc.Int.Seaweed Symp., 5:107-16

McCain, J.C. and W.E. Stout, 1969 Benthic zonation on submarine cliffs in the vicinity of Arthur Harbor, Antarctica. Antarct.Jl.U.S., 4(4):105-6

Neushul, M., 1965 Diving observations of sub-tidal Antarctic marine vegetation. Bot.Mar., 7:234-43

Skottsberg, C., 1941 Observations on the vegetation of the Antarctic Sea communities of marine algae in subantarctic and Antarctic waters. K.Sven.Vetenskapsakad.Handl., 19(4):1-92

__________, 1964 Antarctic phycology. In Biologie antarctique. Comptes-rendus. Premier symposium organisé par le SCAR, Paris, 2-8 septembre 1962. Paris, Hermann, pp. 147-57

Zaneveld, J.S., 1966 The occurrence of benthic marine algae under shore fast-ice in the western Ross Sea, Antarctica. Proc.Int.Seaweed Symp., 5:217-31

ANNEX

SEAWEEDS

Summary of Resources and their Availability

(prepared by Fishery Resources and Environment Division, FAO)

General

In this section an attempt has been made to give quantitative figures for the feasible production of seaweeds in the different fishing areas. This has proved very difficult, and the figures used should be treated with considerable care, though these are believed to provide a reasonable guide as to where the greatest potentials lie, and of the order of magnitude of the possible harvest. The difficulties of estimation are mainly due to the absence of any good estimates of potential harvest, even in those few areas where there has been extensive research or exploitation. The quantitative data are generally confined to figures of current harvest or of standing stock. There is little direct evidence of how either of these are related to sustainable annual harvest. Seaweeds grow continuously during most of the year, and at the same time are decreased by grazing and erosion, so that the annual production can for some species exceed, possibly by several times, the standing stock present at any moment. The potential harvest must be less than the production, but could well be as high as the standing stock. Some supporting evidence for this is given by the ability for some patches of weed to recover within a year of intense cropping. On the other hand, the standing stock of some species, especially in colder or deeper water, may represent the accumulation of several years growth, and the sustainable harvest may only be a fraction of the standing stock. For example, _Furcellaria fustigiata_ harvested off Denmark appeared to be three to five years old, and too intense harvesting led to a decline in the abundance. Estimates of the potential harvest off Scotland were only a tenth of the standing stock. This seems low, implying a period of regrowth of ten years compared with an average of three to four years off Ireland. For the present purposes, and in the absence of a more reliable procedure, figures equal to one-quarter of the standing stock, where available, will be used to give a rough and probably conservative estimate of potential annual harvest.

Finally, it should be noted that, in general, it is highly unlikely that these potentials will ever be fully realized. The problem of accessibility, of harvesting difficulties and transport costs will probably deter the commercial exploitation of many stocks in the forseeable future. Particularly in the case of species in greatest commercial demand, increasing emphasis is more likely to be placed upon cultivation than upon the cropping of naturally-occurring stocks.

Arctic Sea : Area 18

The region generally does not favour large algal growth. In those limited areas where productivity is reasonably high harvesting will be difficult because of the climate and distance from markets. Prospects are poor for significant production, say not more than a few thousand tons.

Northwest Atlantic : Area 21

This includes, in the Nova Scotia area, some of the most productive seaweed beds in the world. Red algae are cropped fairly intensively in several parts of the area (e.g., Prince Edward Island) but harvest could be significantly increased, perhaps threefold. Very large standing stocks of brown algae occur, with an estimated 900 000 t of _Laminaria_ in southwest Nova Scotia. If the total stock for the whole area is little more than twice the figure, the potential would be 500 000 t (using a ratio of standing stock:potential of 4:1).

Northeast Atlantic : Area 27

This is another area with regions of very high productivity, particularly along the open Atlantic coast from northern Norway to Ireland. The area provides some of the major harvests of red and brown algae (in the southern and northern areas respectively). The potential of brown algae off Scotland is estimated at 1 million t. Bearing in mind the further production from the great length of the Norwegian coastline and other areas, the Scottish potential may be not more than one-third of the total. Red algae offer fewer prospects for expansion, but it should be possible to double present harvests.

Western Central Atlantic : Area 31

The area is not rich in coastal seaweeds and there is presently no significant harvest. However, both red and brown algae occur in scattered locations in all parts of the area, and total potential from small-scale operations might be significant, at least some thousands of tons. In addition the standing stock of floating Sargassum weed amounts to some millions of tons, so that the potential from this sourse, if harvestable, could be a million tons or more.

Eastern Central Atlantic : Area 34

Moderate quantities of algae occur in the northern part of the area, but the southern, tropical area seems poor in seaweeds. The present harvest of red algae in Morocco is limited to certain areas, partly due to communication difficulties. If the present harvest rate near the factories could be extended to all the coast southward to Senegal, harvest could be increased five to ten times, or more.

Mediterranean and Black Sea : Area 37

Though densities of seaweed are low, except on the Black Sea, the long coastlines of the area ensure at least a moderate total standing stock, and harvests of red algae are considerable. In the Black Sea a standing stock of 5–6 million t of Phyllophora may be the biggest accumulation of red algae in the world. A harvest of 1 million t annually from this resource seems not unreasonable.

Southwest Atlantic : Area 41

Some of the richest stocks of brown algae occur in the southern part of the area. The extent (10–15 degrees of latitude) is similar to that in the Northwest Atlantic, and the potential may be similar (i.e., about 2 million t). Further north, stocks of both red and brown algae are considerable, if less spectacular, and significant harvests are now being taken. These can probably be increased, and the total potential of red algae might be some 100 000 t.

Southeast Atlantic : Area 47

This area is generally poor in seaweeds, especially in the northern part. Published figures of potential of "hundreds of thousands, if not millions of tons" are almost certainly too high. Extrapolation of quantities of red algae cast ashore (40 t dry weight per km), and of surveys of local stocks of brown algae (6 000 t dry weight in five places) suggest figures of potential in terms of wet weight of 100 000 t upwards.

Western Indian Ocean : Area 51

Resources are generally no more than moderate. Information from the coasts of Africa and the Arabian Peninsula is scarce. Comparison with other areas would suggest resources of perhaps a few tens of thousands of tons. Data from India and Pakistan are more abundant but somewhat inconsistent. Estimates from the best studied (and probably most productive)

areas are quite high, e.g., 20 000 t of red algae potential annual harvest from 32 km. For the whole Indian peninsula the potential of both red and brown algae is probably at least 100 000 t.

In the southern Indian Ocean there are enormous quantities of brown algae round Kerguelen which could well yield a million tons or more if transportation and other practical problems were solved.

Eastern Indian Ocean : Area 57

Information is sparse from the tropical part of the region from India to northwestern Australia, but what there is does not suggest the existence of a rich resource. Substantial quantities of brown algae have been harvested off Tasmania, and greater quantities (1 400 000 t standing stock) exist off southern Australia, though these cannot be easily harvested mechanically. The total potential of brown algae for the whole region might be as much as 500 000 t, but that of red algae substantially less (possibly 50 000 t by extrapolation from other areas).

Northwest Pacific : Area 61

Large quantities are harvested in Japan, Korea and China. Demand seems in excess of supply, and harvest from natural stocks is increasingly supplemented by culture. This suggests that in these countries there is not much opportunity for increasing harvest from natural resources. There is a large standing stock (estimated at a little under 2 million tons) off the coasts of the U.S.S.R., and the potential harvest from this could be added to existing production to provide a reasonable estimate of the total potential (plus say 25 percent to allow for some increased harvest even from the other countries).

Northeast Pacific : Area 67

The region is very rich in kelps. Surveys have been made from 1911 onwards but there appears to be some confusion in the reported figures between standing stock, productivity, and potential harvest. However, even with the most conservative interpretation of the survey data and of the possible cropping rate, the potential harvest is very high, probably at least 1 500 000 t. Red algae are very scarce.

Western Central Pacific : Area 71

Seaweeds are widely eaten in the region, but there is little quantitative data on the current harvest, still less on the potential. Allowing for non-reporting of some parts of the present harvest, and for increased harvest from the less intensively harvested grounds, it is likely that the potential might be at least five times the presently reported figures.

Eastern Central Pacific : Area 77

This area is very rich in seaweeds and supports one of the larger seaweed industries. Estimates of potential harvest of kelps (mainly Macrocystis) run as high as 35 million t. This may be high, but a very safe conservative figure, an order of magnitude lower, is still a very large harvest. Red algae are harvested locally in both the U.S.A. and Mexico, and production could be increased.

Southwest Pacific : Area 81

Moderate quantities of red algae occur off Australia and New Zealand, and there is some commercial harvesting. Brown algae occur in more substantial quantities in the southern parts of New Zealand.

Southeast Pacific : Area 87

This area, and the coast of Chile in particular, is very rich in seaweeds. Red algae are mainly found from central Chile northwards, while brown algae dominate the southern waters, where the Magellan Straits hold one of the richest untapped seaweed resources in the world.

***

Potential and Actual Harvests of Seaweeds

(thousands of tons wet weight)

Area	Red algae: Recent harvests 1/	Red algae: Potential output 2/	Brown algae: Recent harvests 1/	Brown algae: Potential output 2/
18 Arctic Sea	-	-	-	-
21 NW Atlantic	35	100	6	500
27 NE Atlantic	72	150	208	2 000
31 WC Atlantic	-	(10)	1	1 000
34 EC Atlantic	10	50	1	150
37 Mediterranean/ Black Sea	50	1 000	1	50
41 SW Atlantic	23	100	75	2 000
47 SE Atlantic	7	100	13	100
51 W Indian Ocean	4	120	5	150 (1 000, Kerguelen)
57 E Indian Ocean	3	100	10	500
61 NW Pacific	545	650	825	1 500
67 NE Pacific	-	10	-	1 500
71 WC Pacific	20	50	1	50
77 EC Pacific	7	50	153	3 500
81 SW Pacific	1	20	1	100
87 SE Pacific	30	100	1	1 500

1/ Recent levels of harvests based upon estimates for 1971-73.

2/ Broad indications of possible annual output.

MAJOR FISHING AREAS FOR STATISTICAL PURPOSES PRINCIPAL